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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 926

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L. O. HOWARD, Chief

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STUDIES IN THE BIOLOGY OF THE MEXICAN COTTON BOLL WEEVIL ON SHORT-STAPLE UPLAND, LONG-STAPLE UPLAND, AND SEA-ISLAND COTTONS.[a]

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INTRODUCTION.

The studies in the biology of the Mexican cotton boll weevil (*Anthonomus grandis* Boh.) upon which this paper is based were con-

[a] The cotton varieties used in these studies were a short-staple upland cotton known as King, a long-staple variety known as Webber No. 49, and a sea-island cotton known as Hope Straight.

ducted at Madison, Fla., during the years 1918 and 1919. The results recorded herein in addition to representing the first serious study of the boll weevil east of the Mississippi River also indicate the rapidity with which the weevil is adapting itself to new environmental conditions in its spread eastward.

Owing to the very decided effect of climatic factors on the biology of the boll weevil, it has been found necessary to study the development of the weevil under both field and outdoor insectary conditions.

In order to throw some light on the possibility of growing sea-island cotton under weevil conditions, a comparative study of the biology of the weevil on upland, long staple, and sea-island cottons is included herewith. Since all methods of control are usually based upon facts secured from biological studies, the results of the life-history studies recorded herewith are of considerable importance to the cotton growers east of the Mississippi River.

HISTORICAL REVIEW.

A review of the studies in the life history of the boll weevil is presented herewith.[1] This review is of interest in that it shows the times and conditions under which studies have been conducted.

The earliest work was that at Victoria, Tex., in 1902 and 1903, the results being published early in 1904.[2] This was followed by similar investigations at the same place during 1904, and the results of these studies were included in a bulletin issued in 1905.[3]

During 1910 similar investigations were conducted at Tallulah, La., and the results were published in 1911.[4]

Then, in 1912, these studies and such others as had been made elsewhere were brought together in a large bulletin.[5]

During 1913 another series of studies was conducted at Victoria, Tex., to check those which had been made at the same place 10 years earlier. It was found that the weevil had made a number of important changes in its life history, principal among these being a much greater adaptability to plants other than cotton as food. The biology of the Arizona Thurberia weevil was also studied, and this variety was hybridized with the Texas cotton weevils. The results of these studies are included in three papers.[6]

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[1] Quoted from Howe, R. W., Bul. 358, U. S. Dept. Agr., p. 2–3.

[2] Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bur. Ent. Bul. 45, 116 p., 16 pl., 6 figs., 1904.

[3] Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. of Agr. Bur. Ent. Bul. 51, 181 p., 23 pl., 8 figs., 1905.

[4] Cushman, R. A. Studies in the biology of the boll weevil in the Mississippi Delta region of Louisiana. *In* Jour. Econ. Ent., v. 4, no. 5, 1911. p. 432–448.

[5] Hunter, W. D., and Pierce, W. D. Mexican Cotton Boll Weevil. U. S. Dept. of Agr. Bur. Ent. Bul. 114, 188 p., 22 pl., 34 figs., 1912.

[6] Coad, B. R., and Pierce, W. D. Studies of the Arizona Thurberia weevil on cotton in Texas. Proc. Wash. Ent. Soc., v. 16, no. 1. p. 23–28. 1914.

Coad, B. R. Feeding habits of the boll weevil on plants other than cotton. U. S. Dept. Agr. Jour. Agr. Res., v. 2, no. 3, p. 235–245. 1914.

Coad, B. R. Recent studies of the Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bul. 231, 34 p., 1 fig. 1915.

In 1914 the life history and habits of the Arizona weevil were studied under natural conditions in the mountains near Tucson, Ariz. These studies are discussed in two papers.[7]

Thus it is seen that these studies embrace a wide range of time and conditions. In fact, the conditions of humidity, rainfall, temperature, altitude, soil, etc., include practically all extremes found in the cotton belt.

SCOPE OF THE PRESENT LIFE-HISTORY STUDIES.

The biological studies of the boll weevil at Madison, Fla., during the year 1918, included a thorough study of the boll weevil under outdoor insectary conditions on both upland and sea-island cottons. The main object of this study was to determine the difference, if any, in the weevil's biology on the two kinds of cotton. During the month of August, 1918, a small series of experiments was made to determine the length of the developmental period of the weevil from egg to adult under actual field conditions. The results of the field studies indicated conclusively that a wide variation existed in the length of time required for the developmental period of the weevil under insectary conditions compared with the true developmental period under normal field conditions. Consequently the studies in the biology of the weevil during the year 1919 were arranged to include a thorough study of the field biology of the boll weevil. Insectary studies in the biology of the weevil were conducted at the same time the field tests were under observation, to serve as a check.

METHODS USED IN THE STUDY OF THE BOLL WEEVIL UNDER OUTDOOR INSECTARY CONDITIONS.

The numerous experiments of 1918 were conducted in a specially constructed outdoor insectary at the Madison, Fla., laboratory (fig. 8). The sides of the insectary building were constructed entirely of 16-mesh galvanized wire screen from the floor to the ceiling, which permitted free air circulation at all times. The roof of the insectary building extended 2 feet over the sides of the building, preventing the direct rays of the sun from touching any of the breeding jars. All the insectary breeding work was conducted in glass tumblers half filled with white sand. The sand was kept constantly moist. Lantern globes with cheesecloth covers were used for the longevity experiments.

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[7] Coad, B. R. Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. U. S. Dept. Agr. Bul. 233, 12 p., 4 pl. 1915.

Coad, B. R. Studies on the Biology of the Arizona Wild Cotton Weevil. U. S. Dept. Agr. Bul. 344, 23 p., 2 pl., 1 fig. 1916.

METHODS USED IN THE STUDY OF THE BIOLOGY OF THE BOLL WEEVIL UNDER FIELD CONDITIONS.

Large 16-mesh galvanized-wire screen cages 3 by 3 by 4 feet high were used in conducting the field biological studies of the weevil. The cotton plants used in the breeding work were first examined carefully to make certain that no infested squares were present. The large cages were then placed over the plants and a male and a

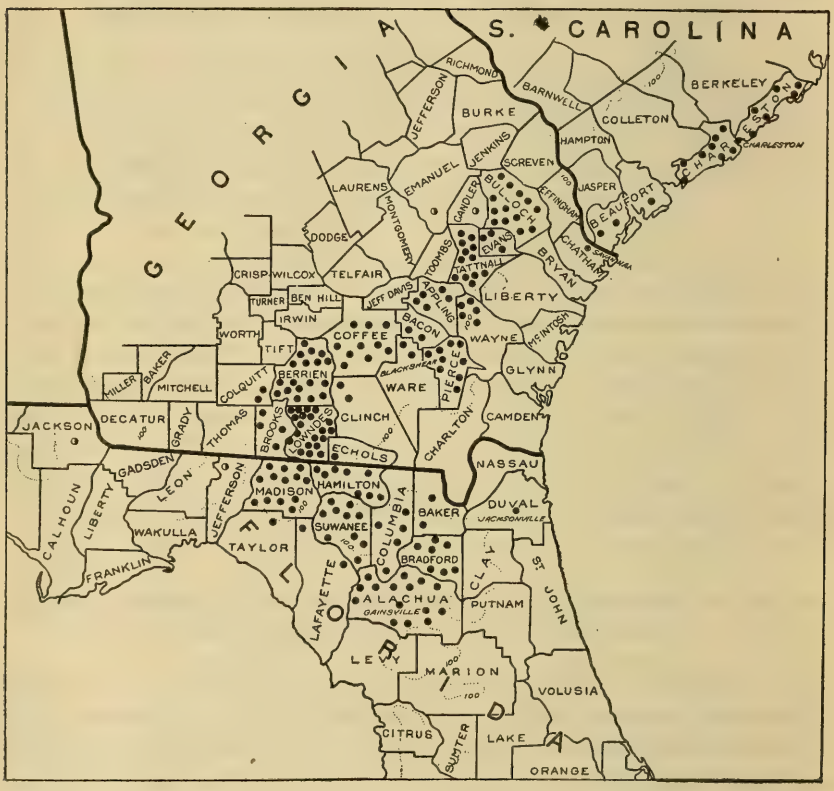

FIG. 1.—Map of the sea-island cotton area of the United States showing distribution by counties. Each dot represents an average production of 500 bales. (From Orton, Bur. Plant Industry, U. S. D. A.)

female boll weevil liberated in each cage. On the following day all squares found with egg punctures were recorded, each infested square bearing a light string tag showing the number of the weevil and the date of the egg puncture. After the squares were examined and tagged the cage and weevil were removed to a noninfested plant and the process repeated. Daily observations were made on the plants bearing the tagged squares and the date the infested square dropped off the plant was recorded on the tag. As soon as the infested squares dropped off the plants they were placed in a field hatchery

(fig. 7). The field hatchery consisted merely of a certain area in the cotton field about 20 feet square. The infested squares were placed in the hatchery beneath the cotton plants in the natural position of fallen squares. After 15 days from the date of egg puncture the infested squares were placed in small wire-screen hatching cages (fig. 7). The hatching cages were constructed of 16-mesh wire without bottoms and protected the infested squares in such a manner that the squares received about the same amount of sunshine and moisture as under normal field conditions. Maximum and minimum thermometers were installed in the field hatchery (fig. 9). Both instruments were resting on the soil in order that the exact minimum and maximum temperatures to which the developing weevil was subjected under field conditions might be determined.

Ten hibernated male and female weevils were used to secure the developmental period of the first generation of weevils on upland cotton. In addition, 10 hibernated female weevils that had not been fertilized were used to determine the effect of nonfertilization after emergence from hibernation on the progeny produced. When the first generation weevils became adults 10 pairs were selected and used for securing the fecundity records on upland, long staple, and sea-island cottons. The fecundity records for the second generation on upland cotton were secured in a like manner. After the 15th of August, however, the weevils had developed so rapidly in the field that it was necessary to discontinue the study of the developmental period of the weevil for each successive generation.

For securing the effect of the lower fall temperatures on the developmental period of the weevil, upland cotton plants were stripped of all cotton squares and then caged. As soon as the plants grew new squares female weevils were placed in the cages for oviposition purposes. About every 20 days a new series of developmental studies was inaugurated. This process was continued until frost killed the cotton plants in late fall.

FOOD PLANTS OF THE BOLL WEEVIL.

Owing to the economic importance of the question as to whether or not the boll weevil can adapt itself to plants other than cotton for food, this phase of the life history has been carefully studied in practically every section of the cotton belt.

The boll weevil has as regular food plants the cultivated cottons of the United States, Mexico, Cuba, and Central America, and certain wild cottons, including *Gossypium davidsoni* on the coast of the Gulf of California, and also the so-called wild cotton, *Thurberia thespesioides*, in Mexico and Arizona.

The breeding experiments of Coad and Howe, both published, show that the weevil can live on Hibiscus, and Coad reared an adult from Hibiscus, but the weevil can not normally attack the plant. So far as we know, there are no plants growing in Florida or the southern States that are adapted to serve as food plants of the boll weevil.

THE BOLL WEEVIL ON SEA-ISLAND COTTON.

FEEDING EXPERIMENTS TO DETERMINE THE PREFERENCE SHOWN BY THE BOLL WEEVIL FOR SEA-ISLAND COTTON.

A known number of adult boll weevils were placed in battery jars and allowed to feed on bolls, squares, and leaves. Each jar contained both sea-island and upland bolls, squares, and leaves, and careful records were taken every two hours to determine whether there was any preference by the weevil for either of the two types of cotton fruit and foliage. The experiments were conducted in an outdoor insectary where normal atmospheric conditions prevailed. The data obtained in order to ascertain whether there is any preference by the boll weevil for sea-island as compared with upland cotton are given in Table I. The records presented in this table show that the boll weevil seems to prefer sea-island foliage to upland foliage, and that it shows a distinct preference for sea-island bolls compared with upland bolls. It appears also that there is a tendency to feed on upland squares in preference to sea-island squares.

TABLE I.—*Feeding choice of boll weevil between sea-island and upland cotton, Madison, Fla.*

Food.	Number weevils used in experiment.	Total number individual observations.	Total number of times weevils were observed.			Percentage of feedings recorded on—	
			Feeding on upland cotton.	Feeding on sea-island cotton.	Resting on cage.	Upland cotton.	Sea-island cotton.
Bolls	10	290	64	118	108	22.0	40.6
Squares	10	290	135	110	44	46.9	37.9
Leaves	10	290	77	129	84	26.5	44.4
Total	30	870	276	357	236	[1] 31.8	[1] 40.9

[1] Average.

In Table I attention is called to the preference by the boll weevil for sea-island bolls over upland bolls in the experiments conducted on the feeding habits of the weevil. In 1917, in order to secure further data on this phase of the weevil's attack, the writer examined at random each week 100 grown bolls of each variety of upland and sea-island cottons that were still green, beginning on the 19th of July, the

bolls being collected under similar field conditions. These records were continued throughout August and to the 1st of September. Table II shows the results of this examination:

TABLE II.—*Record of weevil infestation in green bolls of sea-island and upland cottons, Madison, Fla.*

Date of examination.	Total number bolls examined.	Upland cotton bolls.		Sea-island cotton bolls.	
		Number clean.	Number punctured.	Number clean.	Number punctured.
1917.					
July 19	200	91	9	74	26
July 26	200	89	11	81	19
Aug. 4	200	92	8	69	31
Aug. 11	200	92	8	69	31
Aug. 20	200	91	9	61	39
Aug. 25	[1] 600	36	64	[2] 166	[3] 334
Sept. 1	200	38	62	29	71
Total	1,800	529	171	549	551
Per cent punctured			24.4		50.09

[1] 500 sea-island. [2] 33 per hundred. [3] 67 per hundred.

A careful study of Table II shows that the number of weevils attacking sea-island bolls was far greater than the number attacking upland bolls. Observations in the field also show that a great many more weevils are to be found feeding on the sea-island bolls than on upland cotton bolls.

LONGEVITY OF ADULT BOLL WEEVILS ON UPLAND AND SEA-ISLAND COTTON.

The length of time adult weevils live on upland cotton has been determined for several different times and places. The object of the longevity tests at Madison, Fla., was to determine whether there was any considerable difference in the length of life of weevils fed on upland and sea-island cottons.

Table III gives the observations on the longevity of the weevil when fed upon different parts of the upland cotton plant. The maximum longevity of 84 days was shown by a male weevil that had hibernated over the preceding winter and emerged from hibernation during the month of April. The average longevity for hibernated weevils without food was 12.7 days, compared with an average of 18.8 days for hibernated weevils fed on cotton plantlets. Adult weevils of the first and second generations lived an average of 24.3 days on cotton squares and 12.3 days on green cotton bolls.

Table IV gives the data concerning the longevity of boll weevils on sea-island cotton. The maximum longevity on sea-island cotton

TABLE III.—*Longevity record of boll weevils, summary of the observations at Madison, Fla., 1918.*

Date.	Kind of food.	Males.				Females.				Both sexes.		
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	Source of weevils.
				Days.	*Days.*			*Days.*	*Days.*	*Days.*	*Days.*	
Feb. 22 to 28	No food	56	589	13.3	33	33	402	12.1	34	34	12.7	Hibernated.
Mar. 1 to 31	do	48	712	14.8	40	49	900	18.3	53	53	16.5	Do.
Apr. 1 to 30	do	26	365	14.03	27	27	352	13.03	34	34	13.5	Do.
May 1 to 31	do	23	198	8.6	15	12	100	8.3	14	15	8.4	Do.
June 1 to 30	do	1	27	2.7	27							Do.
Total		154	1,891			121	1,754					
Average				10.68				12.93			12.7	Do.
Maximum					40				53	53		
Mar. 1 to 21	Upland plantlets	25	596	23.8	81	35	711	20.3	76	81	22.0	Do.
Apr. 1 to 30	do	17	376	22.1	84	21	412	19.6	34	84	20.8	Do.
May 1 to 31	do	24	358	14.8	39	5	61	12.5	27	39	13.6	Do.
Total		66	1,330			61	1,184					
Average				20.2				17.4			18.8	Do.
Maximum					84				76	84		
June 26 to 30	Upland squares	127	2,680	21.1	74	52	1,139	21.9	70	74	21.5	First generation.
July 20 to 21	do	20	412	20.6	38	17	407	23.9	50	50	21.5	Second generation.
Total		147	3,092			69	1,546					
Average				20.8				22.9			24.3	
Maximum					74				70	74		
July 6 to 8	Upland bolls	34	543	15.9	49	36	472	13.1	47	49	14.5	First generation.
July 24 to 31	do	19	161	8.4	19	2	24	12	12	19	10.2	Second generation.
Total		53	704			38	496					
Average				12.1				12.5			12.3	
Maximum					49				47	49		
Total upland cotton		420	7,017	15.94		289	4,980	16.43	76	84	17	

TABLE IV.—*Longevity of the boll weevil on sea-island cotton, Madison, Fla., 1918.*

Date.	Kind of food.	Males.				Females.				Both sexes.		Source of weevils.
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
				Days.	*Days.*			*Days.*	*Days.*	*Days.*	*Days.*	
Apr. 1 to 30	Sea-island plantlets	3	27	9	11	3	37	12.3	13	13	10.6	Hibernated.
May 1 to 31	do	22	268	12.2	35	7	76	10.9	23	35	11.5	Do.
Total		25	295			10	113					Do.
Average				10.6				11.6			11.05	
Maximum					35				23	35		
June to July	Sea-island squares	91	1,730	19.01	65	81	1,690	20.4	67	67	19.7	First generation.
July 6 to 25	do	23	196	8.4	18	6	44	7.3	13	18	1.8	Second generation.
Total		114	1,926			87	1,734					
Average				13.7				13.8			10.7	
Maximum					65				67	67		
July 6 to 9	Sea-island bolls	32	539	16.5	52	62	1,203	19.4	43	52	17.9	First generation.
July 24 to 28	do	20	201	10.05	17	8	124	15.5	33	33	12.7	Do.
Total		52	740	13.2		70	1,327	17.4				
Total sea-island cotton		191	2,961			167	3,174					
Average				12.5				14.2			12.3	
Maximum					65				67	67		

was made by a first-generation female weevil that became adult during the latter part of June. This weevil lived a total of 67 days. The maximum length of life for the male weevils was also recorded for a first-generation weevil that became adult during the latter part of June. This weevil lived a total of 65 days. The average longevity for hibernated weevils fed with sea-island cotton plantlets was 11.05 days. The weevils lived 10.7 days on sea-island squares and 15.3 days on green sea-island cotton bolls. By comparing the average longevity of the weevil on sea-island cotton with the average longevity on upland cotton, it is clearly demonstrated that there is little, if any, difference in the food value of sea-island and upland cotton on the longevity of adult weevils.

THE SIZE OF THE COTTON SQUARE ATTACKED BY BOLL WEEVILS.

Male and female weevils feed largely on the cotton squares, except in the case of sea-island cotton, where there is a decided tendency to feed upon the bolls as well as the squares. Upland cotton squares grow very rapidly and there is little opportunity afforded for direct feeding on the very small squares, except during the period when the first squares come on the plants and again when all squares are punctured. However, sea-island squares do not grow very rapidly and a large number of the small squares are shed by the plant from feeding and egg punctures. It has been observed that a large number of undersized weevils are produced in sea-island cotton fields. These weevils are largely the result of eggs having been deposited in undersized squares, which resulted in an undersized weevil, owing to the lack of proper larval food (fig. 2). When a large number of sea-island squares are offered a female it has been observed that she invariably chooses the smaller squares for oviposition purposes. No records are available to show the length of the developmental period for weevils developing in undersized squares on sea-island cotton; however, it is not thought that there is much variation from that in large-sized squares. Observations on the size of weevils bred from bolls show that, except in the case of very young bolls which shrivel and dry very rapidly, nearly all weevils produced are of normal size. Sea-island cotton bolls seldom produce small-sized weevils, as the boll is very moist and furnishes much better conditions for weevil development than upland cotton bolls.

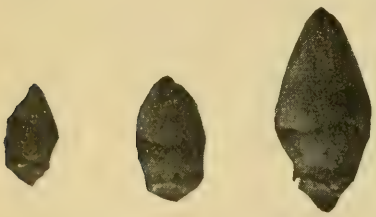

FIG. 2.—Three sizes of sea-island cotton squares chosen for oviposition by the boll weevil.

LOCATIONS SELECTED FOR OVIPOSITION ON SEA-ISLAND AND UPLAND COTTON SQUARES.

Upland cotton squares are usually punctured at the base of the square, as is shown in Plate I, figure 2. During the writer's studies at Thomasville, Ga., in 1916, the majority of the punctures were observed, in the case of sea-island cotton, to be on the upper portion of the square. There is little proliferation around the weevil punctures on the sea-island squares, the punctures being mere specks as compared to those on upland cotton. This characteristic location for egg deposition is shown in Plate I, figure 1.

PERIOD FROM EMERGENCE TO OVIPOSITION.

Female weevils bred in the outdoor insectary required an average period of 8.9 days from the time they became adult to the date of oviposition. The period of time from emergence to oviposition varied from 6 to 20 days for weevils bred under insectary conditions.

Boll weevils bred under normal field conditions appeared to have more vitality than weevils bred under insectary conditions. A record of 38 first-generation weevils bred under normal field conditions gave an average period of 7.07 days from the time they became adult to the date of oviposition.

OVIPOSITION PERIOD OF THE BOLL WEEVIL UNDER INSECTARY CONDITIONS.

The oviposition records for the weevil on upland cotton are presented in Table V. Hibernated female weevils kept with male weevils throughout life deposited eggs over an average period of 35.9 days compared with an average period of 21.7 days for females that were not kept with male weevils. The hibernated fertilized and nonfertilized weevils deposited a total of 3,605 eggs or an average of 7.2 eggs per day per female. During the lifetime of both series of hibernated weevils an average of 171 eggs was deposited by each female. The greatest number of eggs deposited during any one day by a single hibernated female weevil, under insectary conditions, was 20. The heaviest oviposition during the lifetime of both series of weevils was from the fifth to twenty-fifth days (fig. 4). The first-generation weevils deposited eggs for a period of 39.7 days and the second generation over a period of 35.2 days. The average period of oviposition on upland cotton for all weevils under observation was 33.1 days. The relationship between the mean daily temperature and the mean daily oviposition of the hibernated weevils is shown to cor-

respond very closely; that is, the higher the mean daily temperature the higher the average number of eggs until the period of oviposition begins to decline (fig. 3).

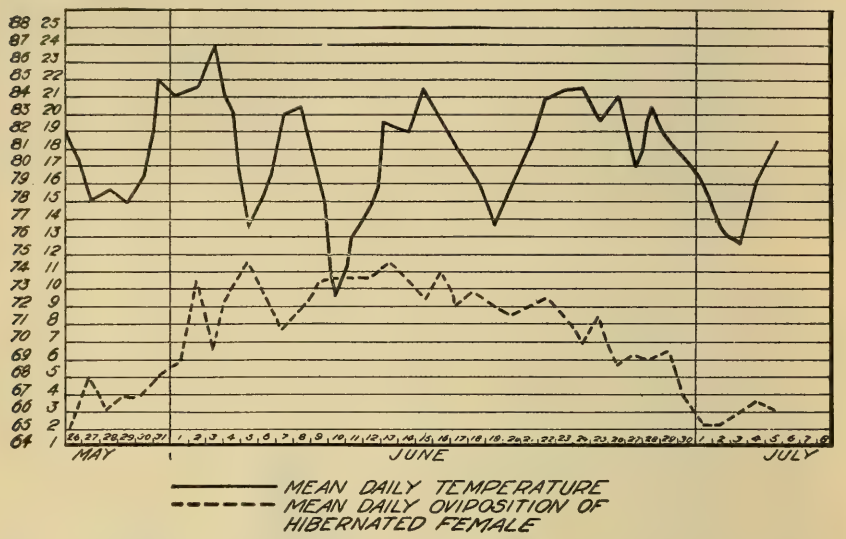

FIG. 3.—Relation of mean daily temperature to mean daily oviposition of hibernated weevils.

The oviposition records of the boll weevil on sea-island cotton differ very little from those on upland cotton under insectary conditions. The female weevils fertilized in the spring deposited eggs for an average period of 31 days and the hibernated weevils

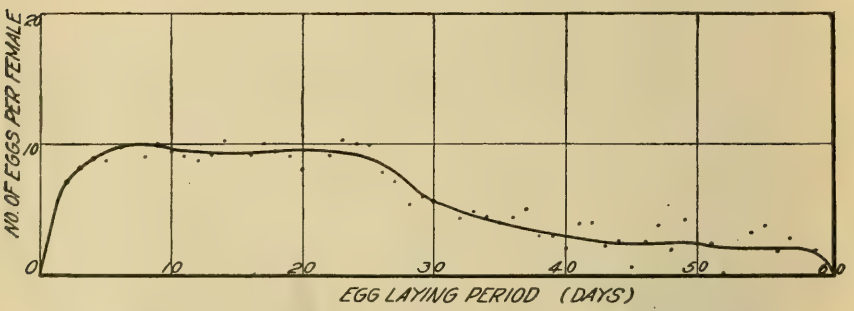

FIG. 4.—Mean daily oviposition of female weevils in upland cotton squares.

fertilized in the fall, for an average period of 27.1 days. The first and second generation weevils deposited eggs for average periods of 35.4 and 33.6 days, respectively. The average oviposition period for the females in sea-island cotton squares is shown to be 31.6 days.

TABLE V.—*Oviposition period of the boll weevil on upland and sea-island cotton squares, insectary records, Madison, Fla., 1918.*

Source of weevils.	Season.	Number of females.	Upland cotton—period.			Number of females.	Sea-island cotton.		
			Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.
			Days.	*Days.*	*Days.*		*Days.*	*Days.*	*Days.*
Hibernated	May-July	12	59	16	35.9	15	52	18	31
Hibernated, fall fertilization.	do	10	53	5	21.7	10	44	16	27.1
First generation	June–August	8	55	31	39.7	10	47	25	35.4
Second generation	July–September.	10	45	20	35.2	10	46	19	33.6
Total		40			33.1	45			31.6

SUMMARY OF THE FECUNDITY OF THE BOLL WEEVIL ON SEA-ISLAND AND UPLAND COTTONS UNDER INSECTARY CONDITIONS.

Table VI gives a summary of the fecundity records of the boll weevil on sea-island and upland cottons. Here it is shown that the average number of eggs per day was highest with hibernated weevils for both types of cotton. The maximum number of eggs per day was made by a first-generation female on upland cotton and the maximum number per day on sea-island cotton was made by a hibernated weevil. The average number of eggs per female on upland cotton was 166.1 and the average number of eggs per day 4.92. On sea-island cotton the average number of eggs per female fell to 113.5 and the average per day to 3.8. These averages compare closely with those secured on upland cotton at Victoria, Tex., in 1913, where the females deposited an average of 212 eggs each and oviposition was at a rate of 5.9 eggs per day.

TABLE VI.—*Summary of the fecundity of boll weevils on sea-island and upland cottons under insectary conditions, 1918.*

Source.	Number of females.	Average number of eggs per female.	Average oviposition period.	Eggs per day.	
				Average.	Maximum.
Upland cotton:			*Days.*		
Hibernated	12	270.3	35.9	7.18	20
Hibernated, fall fertilization	10	117.7	21.7	5.4	19
First generation	8	222.8	39.7	5.6	25
Second generation	10	53.9	35.2	1.5	7
Total	40				
Average		166.1	33.1	4.92	
Sea-island cotton:					
Hibernated	15	214.7	31	7.38	19
Hibernated, fall fertilization	10	122	27.1	4.5	16
First generation	10	79.9	35.4	2.2	11
Second generation	10	37.5	33.6	1.11	7
Total	45				
Average		113.5	31.7	3.8	

THE AVERAGE DEVELOPMENTAL PERIOD OF THE COTTON BOLL WEEVIL UNDER OUTDOOR INSECTARY CONDITIONS.

The data on the average developmental period of the boll weevil under outdoor insectary conditions for sea-island and upland cottons are presented in Table VII. These observations extended over a period of time beginning on May 26 and ending on September 10. The maximum developmental period of any weevil from egg to adult was 18 days and the minimum period 11 days. On upland cotton 506 male weevils bred in the insectary required a total of 7,568 weevil days, or an average period from egg to adult of 14.62 days. A total of 347 female weevils bred under insectary conditions required an average developmental period of 14.8 days. The average period of development for the immature stages bred in upland cotton squares is shown to be 14.91 days.

On sea-island cotton 150 male weevils required 2,214 weevil days from egg to adult, or an average developmental period of 14.82 days. A total of 101 female weevils, bred in sea-island cotton squares, required 1,550 weevil days, with an average period of 15.06 days for development from egg to adult. There is practically no difference in the time required for development of the immature stages of the boll weevil in sea-island and upland cotton squares.

TABLE VII.—*Total developmental period of the boll weevil under insectary conditions, Madison, Fla., 1918.*

Source of weevils.	Larval food.	Oviposition period.	Males.			Females.			Both sexes.		
			Number bred.	Weevil days.	Average period.	Number bred.	Weevil days.	Average period.	Total number bred.	Total weevil days.	Average developmental period.
Upland cotton:					*Days.*			*Days*			*Days.*
Hibernated	Cotton square.	May 26–July 27	201	2,931	14.09	126	1,812	14.38	327	4,726	14.4
Do	do	May 29–July 23	57	816	13.4	41	564	13.7	98	1,380	14.08
First generation.	do	June 14–Aug. 15	208	3,183	15.3	133	2,029	15.2	341	5,218	15.38
Second generation.	do	July 17–Sept 5.	40	638	15.7	47	742	15.9	87	1,380	15.8
Total			506	7,568		347	5,147		853	12,704	
Average					14.62			14.8			14 91
Sea-island cotton:											
Hibernated	Cotton square.	May 26–July 20	67	965	13.5	46	689	13.46	115	1,654	14.3
Do	do	May 25–July 18	34	490	14.4	15	220	14.6	49	690	14.08
First generation.	do	June 21–Aug. 15	33	498	15.09	15	249	16.6	48	746	15.5
Second generation.	do	July 11–Sept. 4	16	261	16.3	25	392	15.6	41	653	15 9
Total			150	2,214		101	1,550		253	3,743	
Average					14.82			15.06			14.94

THE DEVELOPMENTAL PERIOD OF THE BOLL WEEVIL UNDER FIELD CONDITIONS.

Although it has been known that the factors of temperature and humidity influence the development of the boll weevil, and that laboratory breeding methods are more or less artificial, the exact difference between the life history of the weevil under field conditions and in the laboratory has never been determined.

In the experimental work at Madison, Fla., in 1918, it was found that the boll weevil in the field was requiring a considerably longer period for development than had been expected. Records tabulated by Hunter and Pierce[8] showed that the length of the developmental

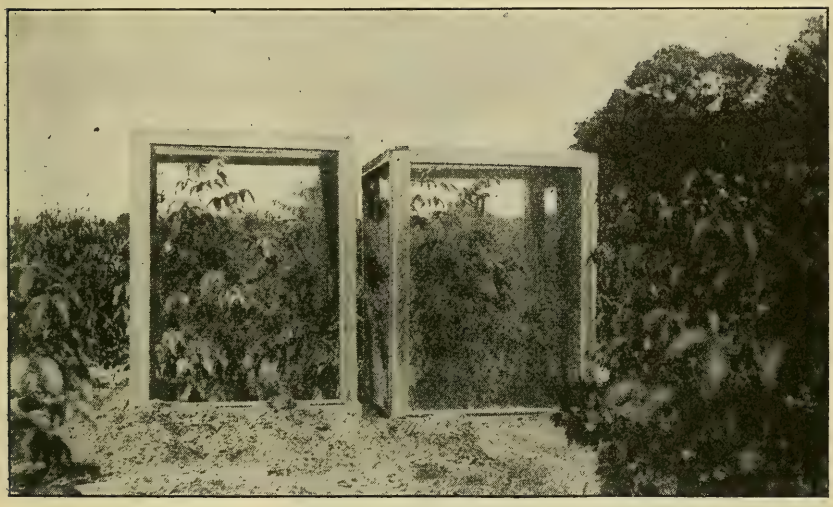

FIG. 5.—Cages used in the oviposition studies of the boll weevil under field conditions, Madison, Fla.

period varied with the length of time the infested squares hung on the plant after egg puncture. The Madison studies fully corroborate this statement.

The field-breeding records were secured under conditions which most nearly simulate nature. A large cage was placed over a cotton plant on which there were no infested squares (fig. 5). A single female or a male and female were liberated in the cage with the non-infested squares. On the second day if any squares were infested these were tagged (fig. 6) and the cage and weevil were then removed to a fresh cotton plant from which all infested squares had been removed. Thus day by day the weevil's maximum oviposition capacity was obtained and the infested squares remained on the plant

[8] Hunter, W. D., and Pierce, W. D. The Mexican Cotton Boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911. Senate Document 305 (U. S. Dept. Agr., Bur. Ent. Bul. 114). 188 p., 22 pl., 33 figs. 1912.

normally, merely being weighted by a light string tag. When the infested squares fell the date was recorded on the tag. All of the infested squares of a certain weevil were assembled in an inclosed area to prevent damage (fig. 7) and placed on the soil under the plant just as they would normally lie. They were watched daily, and only about two days before emergence was expected were covered, still under the plant, by coarse wire screen cages (fig. 7) in order to get the number of weevils that emerged and determine the sex. Hence abnormal conditions were experienced for only about 2 days.

FIG. 6.—The infested squares tagged on the cotton plant, Madison, Fla.

Since these records indicated a much longer developmental period than was recorded in previous bulletins, a complete series of control experiments was conducted in the outdoor insectary (fig. 8).

It will be seen by Table VIII that the developmental period in the tumblers under insectary conditions at Madison is much more rapid than under the most favorable outdoor conditions experienced.

TABLE VIII.—*Showing the length of the developmental period of the boll weevil under insectary and field conditions, Madison, Fla., 1918.*

Ten-day oviposition period.	In insectary, developmental period.				Outdoors, normal developmental period.				Average.
	Number of weevils bred.	Days.			Number of weevils bred.	Days.			Acceleration of insectary days.
		Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.	
June 4–13	370	15.6	13.6	14.8	50	24.5	20.1	21.6	6.8
July 3–13	306	15.2	13.7	14.5	94	24.2	20.8	21.9	7.4
July 31–Aug. 9	87	18	14.8	15.8	54	24.3	19.6	23.2	7.4

The development of the weevil is retarded on the plant, and more so on the ground, and accelerated in the insectary. The outside soil is either too hot or too cool and damp, while the insectary maintains a more even condition, warmer than the plant and cooler than the ground.

If one feels of a leaf or square on a hot day he immediately receives a sensation of coolness. If he lays his hand on the sand in the shade of the plant it feels cool and damp, and if he lays the other hand on the sun-heated sand he experiences a sensation of burning.

Dr. Pierce made a series of temperature measurements on June 21, 1919, in a period of less than 2 hours (from 10 to 12 " daylight-saving

FIG. 7.—The field hatchery, Madison, Fla.

time," or 9 to 11 astronomical time) in which the air temperature about 2 feet above the ground was 88.5° to 89.5° F.

The humidity by sling psychrometer was 68.5 to 69 per cent, by wet bulb 73.5.

The temperature of the sandy soil in the sun was 106.5°, 111°, 111°, and 115° F. at different readings. Once in a while clouds shaded the earth.

In the shade of the cotton plants the temperature of the sandy soil was 92.7°, 93°, and 94° F. at different readings; in other words, the shade of the cotton plant reduced the temperature 14°, but the air temperature was 4° or 5° cooler than the sand under the plant.

Behind the involucre of the square on the plant the temperature was 88° F., and next to the stem of the plant, 2 feet above the ground, it was the same.

When the thermometer was wrapped in cool, green leaves it registered 89° F., but when inserted into a square and wrapped in green leaves it registered 81°.

The thermometer covered one-fourth inch by hot sand in the sun registered 106.5° to 107.5° F.; under one-half inch of sand it registered 99°, under 1 inch 95°, and under 1½ inches of sand 91°.

Thus shallow burial of infested squares would merely give the immature weevils more favorable temperatures and almost insure emergence; while the sun-heated surface soil, even on this moderate day, was heated very close to a fatal temperature.

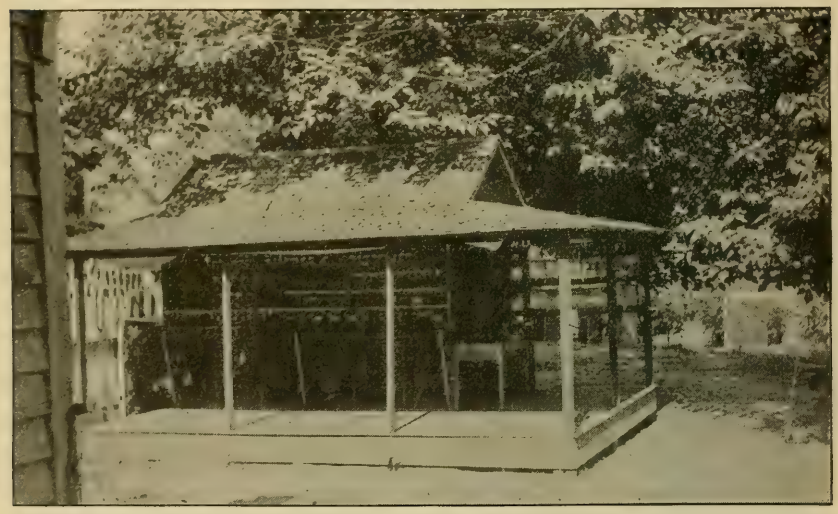

FIG. 8.—Outdoor insectary, Madison, Fla., where the records were secured to check against the field records.

Dr. Pierce then studied the temperature in the field breeding cages and found in the oviposition cage an air temperature of 85° F., a soil temperature in the sun of 108° to 108.5°, in the shade of the wire screen 90° to 94.5°, and in the shade of the plant 92° to 95°. The humidity in the cage was 71.5 per cent, wet bulb 85, while in the open air it was 68.5 per cent, wet bulb 85.5. There is therefore very little difference in the temperature in and out of the cage.

The small wire-screen cages used to cover the squares during the last two days before emergence were then measured. In the shade of the plant the temperature was 94.5° to 96.5° F. and in the sun 103° to 106°. The cage, therefore, serves to mitigate slightly the intense heat.

In the insectary measurements were made in the breeding tumblers. A temperature of 83.5° F. was recorded for the soil in the tumblers, while above the soil the temperature was 86.5° F. Since the tumblers were only moistened once during the hatching period, a temperature

reading on the seventh day gave 84° on the soil and 87° above the soil in the tumblers. On the twelfth day the temperature was 84° on the soil and 86.5° above the soil. Thus, on this particular day, weevils developing in squares on the plant were experiencing 88° F., or probably less, and those in the squares which had fallen on the ground were receiving from 92° to 115° F., according to whether they were shaded or exposed to the sun, while weevils in the insectary were faring well at 83.5° to 87° F. It has been shown that the most favorable temperature for development is between 83° and 84° F.

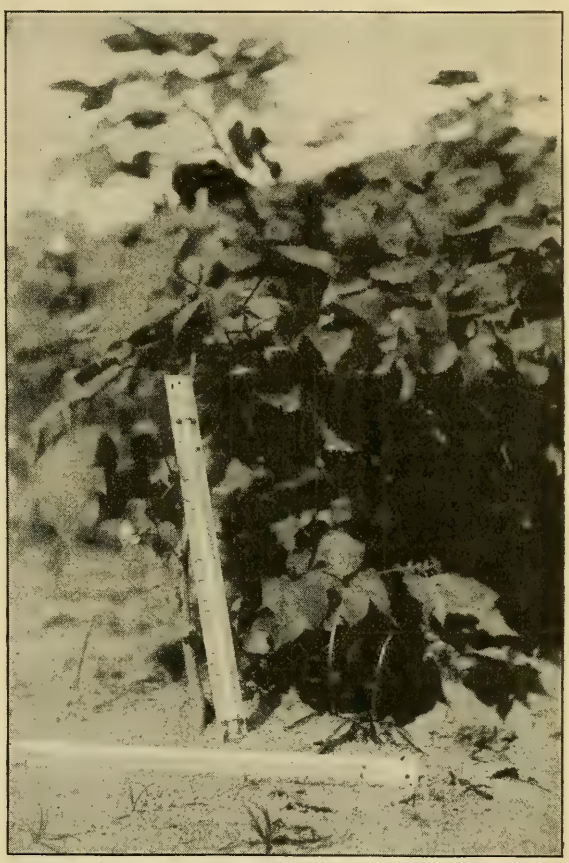

FIG. 9.—Thermometers installed underneath the cotton plants in the field to secure soil temperature, Madison, Fla.

In order completely to check up conditions maximum and minimum thermometers were installed in the field hatchery. Thus the maximum and minimum temperatures experienced by the weevils after the falling of the infested square (fig. 9) were measured.

EGG-LAYING ACTIVITY OF HIBERNATED FEMALE WEEVILS UNDER FIELD CONDITIONS.

Table IX gives the data on the egg-laying activities of female weevils under field conditions on upland cotton squares. The females deposited an average of 76 eggs each at a rate of 8.4 eggs per day. The maximum number of eggs during any one day was 19. It is practically impossible to keep a continuous record of female weevils

under field conditions. Female weevils liberated in large cages over growing cotton plants frequently get killed accidentally, spiders sometimes catch them, and they escape very readily from the cages. The records presented in Table XI really indicate the rate of oviposition per day instead of the average number of eggs deposited per female.

TABLE IX.—*Egg-laying activity of individual hibernated female boll weevils kept with males under field conditions on upland cotton.*

Parent weevil.		Date of first egg.	Date of last egg.	Total number of eggs deposited.	Average number of eggs per day.	Maximum number of eggs per day.	Source of weevils.
Generation.	No.						
Hibernated	A 1	May 29	June 1	28	7	8	Hibernated field collected.
Do	A 2	...do	June 21	218	9.9	19	Do.
Do	A 3	May 31	June 5	33	5.5	7	Do.
Do	A 4	June 1	June 14	80	6.1	9	Do.
Do	A 5	...do	June 8	65	9.3	18	Do.
Do	A 7	June 8	June 15	63	7.9	13	Do.
Do	A 8	June 9	June 13	49	9.8	13	Do.
Do	A 9	June 8	June 14	68	9.7	14	Do.
Do	A 10	...do	June 19	70	5.8	11	Do.
Do	A 13	June 12	June 21	88	11	19	Do.
Do	A 14	...do	June 23	97	8.1	19	Do.
Do	A 16	June 18	June 22	54	10.8	18	Do.
Total				913		168	
Average				76	8.4		
Maximum				218	11	19	
Minimum				33	5.5		

LENGTH OF TIME UPLAND COTTON SQUARES HANG ON THE PLANTS AFTER EGG PUNCTURE.

In Table X are found the data on the length of time squares hang on the plants after egg puncture by the weevil. The average number of days from the time the egg is deposited until it drops off the plant is shown to be 11.5 days. The maximum length of time any square hung on the plant after egg puncture was 19 days and the minimum period 6 days.

The length of time elapsing from the date of falling of the infested square from the cotton plant to the emergence of the adult weevil is shown to be 10.8 days. Practically one-half of the weevil's immature stage is developed while the square is on the plant. The minimum number of days from falling of the infested square to the emergence of the adult weevil was 3 days and the maximum number 19 days.

TABLE X.—*Showing development of weevil as related to the length of time squares hung on plants after egg puncture, eggs deposited by hibernated females on upland cotton.*

Date oviposition began.	Total number squares under observation.	Total number days on plant after puncture.	Minimum number days on plant after puncture.	Maximum number days on plant after puncture.	Average number days from puncture to falling of square.	Total number squares under observation.	Total number days from falling to adult.	Minimum number days from falling to adult.	Maximum number days from falling to adult.	Average number days from falling of square to adult.
May 29	29	315	7	15	11.6	12	122	7	12	10.1
May 27	100	1,125	6	18	11.2	17	185	7	15	10.8
May 31	24	269	8	16	11.2	9	82	7	11	9.1
June 1	33	400	6	17	12.1	11	108	3	13	9.8
Do	24	307	10	19	12.7	2	21	10	11	10.5
June 8	23	265	7	17	10.6	7	79	7	16	11.2
June 9	12	148	6	15	12.3	2	22	10	12	11
June 8	42	482	7	19	11.4	9	105	9	16	11.6
Do	51	514	7	13	10.7	8	107	10	16	13.3
June 12	28	289	6	16	10.3	14	156	9	19	11.1
Do	36	410	6	16	11.3	7	83	10	15	11.8
June 18	19	240	9	19	13.6	4	39	9	11	9.7
Total	421	4,764	85	200	.....	102	1,109	98	167	.....
Average	.....	.....	7.08	16.6	11.5	8.5	.....	8.1	13.9	10.8
Maximum	.....	.....	10	19	13.6	17	.....	10	19	13.3
Minimum	.....	.....	6	13	10.3	4	.....	3	11	9.1

FECUNDITY RECORDS OF HIBERNATED FEMALE BOLL WEEVILS ON UPLAND COTTON UNDER FIELD CONDITIONS.

The data on the fecundity of hibernated female weevils under field conditions are presented in Table XI. Of the progeny produced by the individual female weevils 73 males required 1,536 weevil days, or an average period of 21.7 days, for development from egg to adult. A total of 52 female weevils required 1,145 weevil days, or an average period of 20.2 days, for development of the immature stage. The average period of development for both sexes under actual field conditions was 21.7 days, with a maximum of 24 and a minimum of 19.5 days for the first-generation weevils. A total of 17.99 per cent of the infested squares produced adult weevils. This percentage is remarkably low compared with the generally accepted belief that approximately 35 per cent of the infested squares produced adults. At Madison the Norfolk sandy soil is so well drained that the developing weevils are exposed to terrific heat during the time the square is on the soil before the adult weevils emerge. Consequently a very large mortality occurs among the immature stages of the weevil.

TABLE XI.—*Fecundity record of individual hibernated females of the boll weevil fertilized in spring under field conditions on upland cotton.*

Date oviposition began.	Number eggs deposited normally.	Progeny produced by individual females.									Percentage punctured squares producing adults.
		Males.			Females.			Both sexes.			
		Weevils bred.	Weevil days.	Developmental period.	Weevils bred.	Weevil days.	Developmental period.	Total weevils bred.	Total weevil days.	Period both sexes.	
				Days.			*Days.*			*Days.*	
May 29	28	10	188	20.8	6	124	20.6	16	312	19.5	57.1
Do	218	15	297	21.2	7	148	21.1	22	445	20.2	10.08
May 31	33	7	137	19.6	3	60	20	10	197	19.7	30.3
June 1	80	4	93	23.2	7	166	23.3	11	259	23.5	13.7
Do	65	2	43	21.5	0	0	0	2	43	21.5	13.07
June 8	63	6	132	22	4	92	23	10	224	22.4	15.8
June 9	49	1	22	22	1	23	23	2	45	22.5	4.08
June 8	68	7	170	24.2	3	70	23.3	10	240	24	14.7
Do	70	6	125	20.8	7	152	21.7	13	277	21.3	18.5
June 12	88	5	120	24	3	67	22.3	8	187	23.3	11.4
Do	97	5	104	20.8	7	152	21.7	12	256	21.3	13.6
June 18	54	5	105	21	4	91	22.7	9	196	21.7	13.6
Total	913	73	1,536	.....	52	1,145	.....	125	2,681	.....	.....
Average	76.08	.....	.....	21.7	.....	.....	20.2	.....	.....	21.7	17.99
Maximum	218	15	.....	24.2	7	.....	23.3	22	.....	24	57.1
Minimum	28	1	.....	19.6	0	.....	0	2	.....	19.5	4.08

SUMMARY OF THE DEVELOPMENTAL PERIOD OF THE FIRST-GENERATION BOLL WEEVILS IN UPLAND COTTON SQUARES UNDER FIELD CONDITIONS.

Table XII gives a summary of the period of development in upland cotton squares of first-generation weevils under field conditions, together with the temperature and humidity records. The average period of development in the infested squares while the squares remained on the growing cotton plants is shown to be 10.9 days. During the time the infested squares were on the ground or after they had dropped off the plant the average period of development is shown to be 11.4 days. The average maximum soil temperature was 103.7° F. Since it has been demonstrated that the boll weevil develops most rapidly under a mean temperature of 84° F., the higher temperatures experienced while the square is on the soil retard the developing process and prolong the developmental period of the weevil. Also high soil temperatures are directly responsible for the death of large numbers of immature weevils. At Madison it was observed that a very high percentage of teneral weevils was killed by the heat before the weevils could make an emergence hole in the square.

TABLE XII.—*Summary of development of first generation boll weevils under field conditions on upland cotton.*

Date of oviposition.	Date squares dropped off.	Date hatched.	Total number weevils bred.		Average period of development.			Mean air humidity.	Mean soil temperature.	Average maximum soil temperature.
			Male.	Female.	On plant.	On ground.	Total.			
					Days.	*Days.*	*Days.*			
May 29–June 1...	June 6–June 25.	June 17–June 25.	8	6	11.6	10.1	21.7	65.5	85.4	111.7
May 29–June 21..	June 7–July 8...	June 12–July 10.	15	7	11.2	10.8	22	72.2	82.3	101.6
May 29–June 5...	June 9–June 16.	June 20–June 25.	7	3	10.8	9.4	21.2	65.2	85.5	109.7
June 1–June 14...	June 11–June 24	June 20–July 5..	8	3	11.2	12.7	23.5	76.3	81	101.6
June 2–June 8...	June 11–June 23	June 22–June 25.	2	0	11	10.5	21.5	62.5	85.5	109.7
June 8–June 15..	June 16–June 30	June 30–July 5..	5	4	10.1	12.2	22.3	76.3	81	101.6
June 9 to June 13.	June 18–June 23	July 2–July 5...	1	3	11.5	11.0	22.5	76.3	81	101.6
June 6–June 14...	June 17–July 1..	July 3–July 9...	7	3	10.3	13.7	24	75.96	81.4	101.3
June 8–June 19...	June 16–June 30	July 1–July 5...	5	4	10.4	13.3	23.7	76.3	81	101.6
June 12–June 21..	June 18–July 4..	July 5–July 10..	6	7	9.3	12	21.3	77.2	82.3	101.6
June 12–June 23..	June 19–July 8..	July 2–July 13..	5	7	12	11.8	23.8	79.2	82.8	101.2
June 18–June 22..	June 30–July 8..	July 11–July 13.	4	5	12.5	9.4	21.9	79.2	82.8	101.2
Total.....	.....	.....	73	52	.....	.....	.....	.....	.....	.....
Weighted average.	.....	.....	.....	.....	10.9	11.4	22.4	73.51	82.6	103.7

DEVELOPMENTAL PERIOD OF FIRST GENERATION BOLL WEEVILS ON SHORT STAPLE UPLAND, SEA-ISLAND, AND LONG-STAPLE UPLAND COTTONS UNDER FIELD CONDITIONS.

In addition to the series of hibernated female weevils under observation a series of first generation weevils was used to determine the difference in the length of the developmental period under field conditions on upland, sea-island, and long-staple cottons.

The first generation female weevils deposited eggs at an average rate of 7.6 eggs per day on sea-island cotton. The maximum number of eggs deposited during any one day in sea-island cotton squares was 29.

The 10 female weevils under observation on long-staple cotton squares deposited eggs at an average rate of 6.3 eggs per day. The greatest number of eggs deposited during one day in long-staple squares was 21 eggs.

On upland cotton the 10 female weevils deposited eggs at an average rate of 6.2 eggs per day, with a maximum of 23 eggs deposited by a single female during one day.

On upland cotton the infested squares remained on the plants for an average period of 10.9 days. A period of 11.4 days was the average time required to complete the development of the immature stages after infested squares dropped off the plant.

The average number of days elapsing from the date of egg puncture to the falling of the infested squares was 10.7 on sea-island cotton. The average number of days required to complete the de-

velopment of the immature weevil after the sea-island squares dropped off the plant was 10.4.

The infested squares on the long-staple cotton required 12.3 days from the date of the egg puncture to the falling of the infested square. The time required for the immature weevil stages to complete their development after the long-staple squares dropped off the cotton plants averaged 10.5 days. One of the objections to the long-staple varieties of cotton is the tendency of the infested squares to hang on the plants, protecting the immature weevil stages to a certain extent from natural enemies and mechanical injury.

A total of 92 male weevils of the first generation bred in sea-island cotton squares required 2,006 weevil days or an average period of

FIG. 10.—Shallow wooden troughs filled with crude oil to keep ants out of the weevil hatchery, Madison, Fla.

21.8 days for development of the immature stage. The 75 female weevils bred from the same source required a total of 1,651 weevil days or an average period of 22 days for development from egg to adult. An average period of 21.9 days was required for the development of both sexes of the first-generation weevils in sea-island cotton squares.

The 35 male weevils bred from long-staple cotton squares required a total of 726 weevil days or an average period of 20.7 days from egg to adult. A total of 549 weevil days was required for the development of the 26 female weevils from long-staple cotton squares, or an average of 21.8 days. The developmental period in long-staple cotton squares for both sexes from egg to adult averaged 20.9 days.

A total of 61 male weevils of the first generation bred in upland cotton squares under field conditions required 1,344 weevil days, or an average period of development of 22 days. The 33 female weevils

of the same series required 718 weevil days, or an average developmental period from egg to adult of 21.8 days. The developmental period for both sexes under field conditions averaged 21.1 days from egg to adult.

The total percentage of the infested squares producing adult weevils could not be determined, as a considerable number of the infested squares under observation were detroyed by ants, *Solenopsis* sp. (fig. 10).

COMPARISON OF THE DEVELOPMENTAL PERIOD OF THE IMMATURE STAGES OF THE BOLL WEEVIL UNDER FIELD AND INSECTARY CONDITIONS.

The results of the breeding experiments under outdoor insectary conditions, conducted primarily to check the field breeding records, are tabulated and summarized in Table XIII. The average developmental period under insectary conditions for the hibernated and first-generation weevils in upland cotton squares was 14.5 days. The developmental period of the progeny produced by first generation weevils in long-staple upland and sea-island cottons was 14.2 and 13.7 days, respectively. There is little if any difference in the length of the developmental period of the weevils bred in the three types of cotton squares under insectary conditions. A total of 1,148 weevils which required 16,568 weevil days or an average period of 14.3 days for development under insectary conditions is recorded for the three types of cotton.

The developmental period of the immature stage of the boll weevil under normal field conditions on short-staple upland, long-staple upland, and sea-island cottons is presented in Table XIV. The male weevils bred in upland cotton squares required 21.7 days for development from egg to adult and the females of the same series required a slightly longer period—22.33 days. A total of 323 weevils bred in upland cotton squares under normal field conditions required an average period of 21.9 days for development from the time the egg was deposited to emergence of the adult weevil.

In sea-island cotton squares 92 male weevils required 2,006 weevil days, or an average period of 21.8 days, for development from egg to adult. The 75 female weevils bred from the same source required 1,651 weevil days or an average period of development of 22 days. Both sexes required an average developmental period of 21.9 days from egg to adult.

On long-staple upland cotton 35 male weevils bred in squares under field conditions required 726 weevil days or an average period of 20.7 days for development of the immature stages. The 26 female weevils required 549 weevil days or an average period of 21.8 days for development. Both sexes bred in long-staple upland cotton squares required an average period of development of 20.9 days from egg to adult.

The 551 weevils bred under field conditions from squares of all three types of cotton required a total of 12,012 weevil days or an average period of development of 21.8 days from egg to adult.

The average developmental period of the weevil in all three types of cotton squares under insectary conditions is shown in Table XIII to be 14.3 days from egg to adult. The average developmental period under normal field conditions for weevils bred from all three types of squares is shown to be 21.8 days. Under actual field conditions it is safe to say the boll weevil requires a period of 7.5 days additional time for development, or fully one-half more time than is required under insectary conditions at Madison, Fla.

TABLE XIII.—*Table showing the developmental period of the boll weevil under insectary conditions, 1919.*

Nature of weevils.	Larval food.	Period of oviposition.	Number of males bred.	Male weevil days.	Average period.	Number of females bred.	Female weevil days.	Average period.	Total number of weevils bred.	Total weevil days.	Average period.
					Days			*Days*			*Days*
Hibernated	Upland cotton squares.	June 5–July 25	247	3,692	14.9	123	1,816	14.7	370	5,508	14.8
First generation		July 5–Aug. 19	189	2,765	14.6	117	1,762	14.3	306	4,438	14.5
Total upland cotton.			436	6,457	14.8	240	3,578	14.5	676	9,946	14.7
Long-staple cotton: First generation	Long-staple squares.	July 9–Aug. 2	210	2,953	14.06	154	2,187	14.2	364	5,140	14.1
Sea-island cotton. First generation	Sea-island squares.	July 5–Aug. 9	67	917	13.6	41	565	13.7	108	1,482	13.7
Total all cotton			713	10,327	14.15	435	6,330	14.1	1,148	16,568	14.3

TABLE XIV.—*Showing the total developmental period of the boll weevil under field conditions.*

Nature of weevils.	Larval food.	Period of oviposition.	Males.			Females.			Both sexes.		
			Number of males bred.	Number of male weevil days.	Average period.	Number of females bred.	Female weevil days.	Average period.	Total number bred.	Total weevil days.	Average period both sexes.
Upland cotton:					*Days*			*Days*			*Days*
Hibernated	Cotton sq.	May 29–June 13.	73	1,536	20.9	52	1,145	22.01	125	2,681	20.8
Do	do	June 7–June 22.	23	477	20.7	27	607	22.5	50	1,084	21.6
First generation	do	July 3–Aug. 2	61	1,344	22	33	718	21.8	94	2,062	21.9
Second generation	do	July 31–Aug. 22.	23	539	23.4	31	714	23.03	54	1,253	23.2
Total upland cotton.			180	3,896	21.7	143	3,184	22.33	323	7,080	21.9
Sea-island cotton: First generation	Cotton sq.	June 26–Aug. 4.	92	2,006	21.8	75	1,651	22	167	3,657	21.9
Long-staple cotton: First generation	do	June 30–July 30.	35	726	20.7	26	549	21.8	61	1,275	20.9
Total all three types of cotton.			307	6,628	21.4	244	5,384	22.06	551	12,012	21.8

DEVELOPMENTAL PERIOD OF THE BOLL WEEVIL IN GREEN COTTON BOLLS.

Owing to the fact that large numbers of adult weevils in the field at the time the bolls are set deposit eggs in the bolls almost as readily as they do in the squares, it is almost impossible to secure noninfested bolls for breeding purposes. Therefore the following method for securing the developmental period of the weevil in cotton bolls for upland, long-staple, and sea-island cotton was followed.

Large, healthy, grown bolls were examined for egg punctures. The number of egg punctures was recorded on a light string tag, together

FIG. 11.—Green cotton bolls bagged in muslin to secure records on the immature stages of the weevil, Madison, Fla.

with the date of examination. The boll was inclosed in a thin muslin bag to prevent further infestation and allowed to remain on the plant under normal field conditions until the adult weevil emerged. All weevils that emerged were counted and the sex determined.

During the month of August 200 weevil-infested bolls were bagged (fig. 11) on each of the three types of cotton. Daily examinations were made of the bagged bolls after a period of 10 days had elapsed.

The upland cotton bolls produced 7 male weevils that required 233 weevil days for development, or an average period of 33.2 days. The 6 female weevils bred from upland cotton bolls required a total of 207 weevil days, or an average period of 34.5 days from egg to adult.

The 200 long-staple or thick-rind cotton bolls produced 8 male weevils that required 250 weevil days from egg to adult, or an average

period of 31.2 days. A total of 298 weevil days was required by the 10 female weevils bred from long-staple cotton bolls, or an average period of 29.8 days from egg to adult. The sea-island cotton bolls produced 30 male weevils that required 953 weevil days from egg to adult, or an average developmental period of 31.7 days. A total of 18 female weevils bred required 623 weevil days, or an average period of 34.6 days for development from egg to adult. (Fig. 12.)

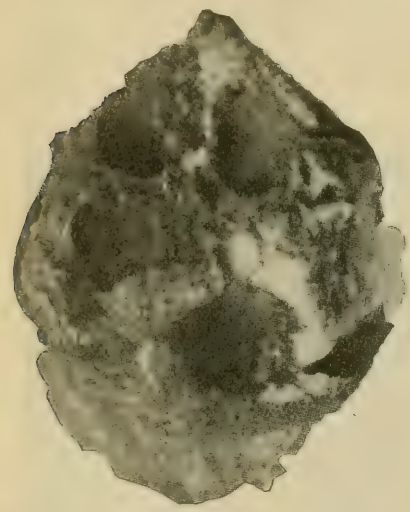

FIG. 12.—Four cavities in which four boll weevils were reared in a sea-island cotton boll, Madison, Fla.

Since the bolls had probably been punctured from 5 to 7 days before they were bagged, it is evident that the developmental period of the boll weevil in green cotton bolls is approximately 35 to 40 days under the most favorable summer temperatures and longer during the fall months. Howe[9] states that the developmental period of the boll weevil in green upland cotton bolls at Tallulah, La., under insectary conditions, was 16.2 days. At Madison, Fla., the developmental period of the boll weevil in green cotton bolls under actual field conditions more than doubles Howe's record.

FECUNDITY OF THE BOLL WEEVIL IN UPLAND AND SEA-ISLAND COTTON BOLLS.

Throughout the season of 1918 attempts were made to secure records of the fecundity of the weevil in green cotton bolls. More than 200 pairs of weevils were under observation at different times during the season. In no case were clear and concise records secured for individual weevils. For some peculiar reason the females did not oviposit freely in the green cotton bolls under insectary conditions.

PREFERENCE SHOWN BY FEMALE WEEVILS FOR OVIPOSITION IN SEA-ISLAND AND UPLAND COTTON FRUIT.

An experiment to determine the preference by the boll weevil for deposition was made by confining six female weevils over upland and sea-island cotton fruit. The female weevils were confined in a large battery jar on moist sand. Fresh squares and bolls of both sea-island and upland cottons were placed in the jar each morning

[9] Howe, R. W. Studies of the Mexican Cotton Boll Weevil in the Mississippi Valley, U. S. Dept. Agr. Bul. 358, p. 28. 1916.

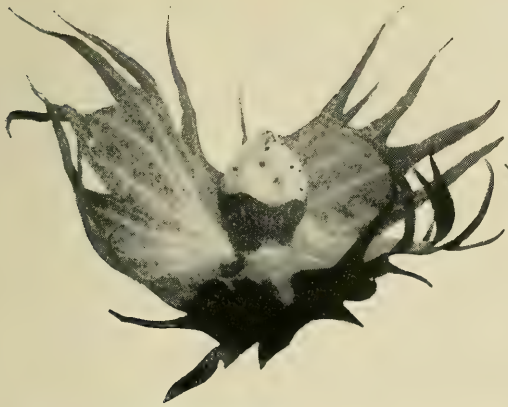

FIG. 1.—SHOWING POSITION OF EGG PUNCTURES ON SEA-ISLAND COTTON.

FIG. 2.—SHOWING POSITION OF EGG PUNCTURES ON UPLAND COTTON.

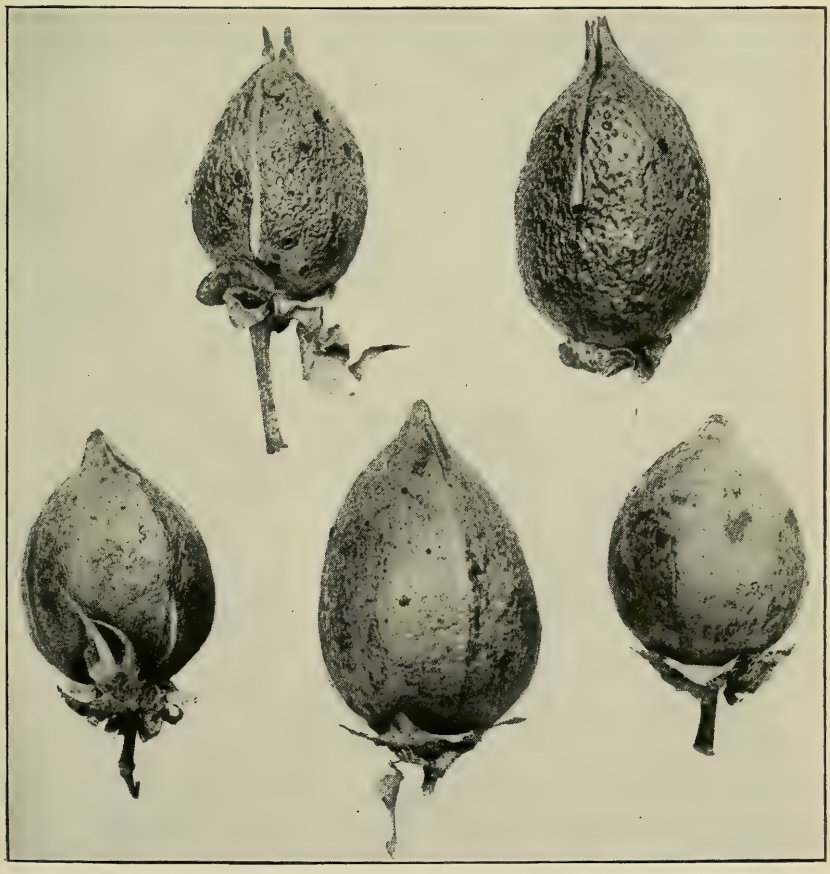

FIG. 3.—THE DIFFERENCE IN STRUCTURE BETWEEN SEA-ISLAND COTTON BOLLS (ABOVE) AND UPLAND COTTON BOLLS (BELOW).

THE BOLL WEEVIL ON SEA-ISLAND AND UPLAND COTTONS.

and all fruit in which eggs had been deposited was recorded and removed from the jar. The records of the experiment are presented in Table XV. A total of 49 eggs were deposited in upland squares compared with 17 eggs deposited in sea-island cotton squares. Eggs were deposited in six sea-island bolls, but in none of the upland cotton bolls.

TABLE XV.—*Preference shown by females of the boll weevil in locations for oviposition on sea-island and upland cotton, Madison, Fla., 1918.*

Date.	Eggs in—			
	Upland squares.	Sea-island squares.	Upland bolls.	Sea-island bolls.
July 17	0	0	0	3
July 18	0	0	0	1
July 19	5	0	0	2
July 20	3	0	0	0
July 21	9	4	0	0
July 22	3	2	0	0
July 23	6	3	0	0
July 24	2	2	0	0
July 25	4	3	0	0
July 26	5	0	0	0
July 27	3	1	0	0
July 29	4	2	0	0
July 31	5	0	0	0
Total	49	17	0	6

COMPARISON OF THE NUMBER OF BOLL WEEVILS THAT EMERGE FROM UPLAND AND SEA-ISLAND SQUARES AND BOLLS.

The writer placed 4,000 upland squares in a large wire-screen cage on August 26, 1918. The squares were carefully examined to determine whether each square was punctured and large enough to support the developing weevil larva. Similarly, 4,000 sea-island squares were put up on the same date.

From the 4,000 upland squares 1,476 adult weevils emerged soon after the squares were placed in the large cage, or a percentage of 36.9. From the sea-island squares 1,979 weevils, or a percentage of 49.4, emerged.

One thousand five hundred upland and 1,500 sea-island bolls were placed in a large wire-screen cage on September 1, 1918, to determine whether more weevils would hatch from sea-island than from upland bolls. It is shown in Plate I that there is a decided difference in structure between the two types of bolls, the sea-island being oblong, with a soft and oily texture. One hundred weevils hatched from the upland bolls compared to 650 weevils from the sea-island-cotton bolls.

From the records secured at Madison, Fla., during 1918, it appeared that the majority of egg punctures in sea-island bolls produced adult boll weevils. It not infrequently happened that as many as from four to eight weevil larvæ would complete their life cycle in a single boll.

THE RELATION OF TEMPERATURE TO THE BIOLOGY OF THE BOLL WEEVIL.

The relationship of temperature to the biology of the weevil has been thoroughly studied for the adult weevil. Little information is available, however, showing the effect of temperature on the immature stages of the weevil. For years the Bureau of Entomology has made so-called status examinations in different parts of the weevil-infested area of the cotton belt to determine the percentage of mortality caused by the heat and dry weather in the immature stages of the weevil. From an examination of 91,082 immature weevil stages Hunter and Pierce[10] found 23.8 per cent killed by heat and dryness. This examination extended over the different months of the growing season from May to October. The relatively small percentage of mortality among the immature weevil stages recorded in this examination is misleading, because the life of the immature weevils was not followed through until the weevil became adult. From the writer's observations at Madison, Fla., the critical period of the immature weevil caused by intense heat seems to extend to the teneral adult stage. Hundreds of teneral adult weevils were observed in squares in the field hatchery that were killed by the heat before they could make an emergence hole in the square. Therefore an examination made to determine the percentage of mortality caused by heat and dryness on any given date is misleading for the simple reason that, although the percentage of immature stages dead may not run very high at the time of examination, yet if it were possible to follow these stages through to emergence of the adult weevil the figures might be trebled. As a concrete illustration, on June 25, 1919, Dr. Pierce examined 451 weevil stages in fallen brown squares taken from plants on which tagged squares were hanging or had fallen. Of the 451 stages examined 134, or a percentage of 38.95, had been killed from climatic causes. At the time this examination was made the writer had 1,378 fallen punctured squares that were tagged on the day of egg-puncture under observation for breeding records. Dr. Pierce's examination indicated that 38.95 per cent of the 1,378 fallen punctured squares would not hatch weevils, since the punctured squares used in his examination were taken from underneath the plants where tagged squares belonging to the writer were lying. However, of the 1,378 squares that were tagged, only 134, or 9.7 per cent, produced adult weevils. It is evident that a field examination is misleading in so far as the percentage of control of the immature weevil stages by heat and dryness is concerned unless these stages can be followed through to the emergence of the adult weevil.

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[10] Hunter, W. D., and Pierce, W. D., op. cit.

TEMPERATURES FATAL TO THE IMMATURE STAGES OF THE BOLL WEEVIL

Owing to the lack of proper soil thermometers, it was impossible to determine accurately the fatal temperatures for the immature stages of the weevil. The thermometers in use frequently recorded maximums of 115 to 125° F., and under these maximum soil temperatures it seems safe to assume that not more than 10 per cent of the immature weevils will survive on Norfolk sandy soils such as occur at Madison, Fla.

THE EFFECT OF TEMPERATURE ON THE LENGTH OF THE DEVELOPMENTAL PERIOD OF THE IMMATURE STAGES OF THE BOLL WEEVIL.

Mean temperature and humidity either shorten or prolong the developmental period of the immature weevil. The exact amount of humidity required for development under optimum conditions has never been determined. A mean temperature of 84° F. has been determined as the optimum temperature for development of the immature weevil stages. Were it possible for the immature weevil to have the exact amount of humidity and a mean temperature of 84°, the developmental period of the immature stages would be approximately 8 days. Temperature and humidity, however, are never just in the right proportion and so the period of development varies under different conditions.

THE EFFECT OF TEMPERATURE ON THE LENGTH OF THE DEVELOPMENTAL PERIOD UNDER INSECTARY CONDITIONS.

Under insectary conditions the development of the weevil has been shown to be approximately 14.3 days from egg to adult. This period of development is much shorter than the period under field conditions owing to the smaller variation in extremes of temperature. The mean temperature at Madison, Fla., under insectary conditions during the months of June, July, and August approximates 81° F. according to the United States Weather Bureau records. The average mean temperature is lower by 3° than is required for the optimum developmental conditions. Therefore it is to be expected that the developmental period would be approximately 14 days under insectary conditions.

THE EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF THE IMMATURE STAGES OF THE WEEVIL UNDER FIELD CONDITIONS.

Under field conditions the development of the immature weevil is considerably retarded and prolonged. It has been shown that the infested squares remain on the plants for approximately 11 days after egg puncture. For fully 8 days after egg puncture the sap continues to flow to the injured squares and keeps the temperature lower than is required for proper weevil development. At night the

transpiration of the plant further lowers the temperature surrounding the developing weevil, and for 12 of the 24 hours of the day the minimum temperatures below 84° F. are retarding and prolonging the developmental period. After the infested square drops off the plant it is exposed to the high soil temperatures which range well above 100° F. from 10 a. m. to 5 p. m. The immature weevil is again retarded and all temperatures above 84° F. as well as below 84° F. act as retarding factors.

THE DEVELOPMENTAL PERIOD OF THE BOLL WEEVIL ON DIFFERENT TYPES OF SOIL.

Although the field biology of the boll weevil has not been studied for the different types of soil, the results secured at Madison, Fla., indicate certain generalizations which will probably hold good for the majority of cases.

In addition to heat and dryness soil drainage must be considered. Poorly drained soils such as are found in the Mississippi Delta and the swamps and river bottoms will probably show an average period of development from egg to adult to be a few days shorter than it would be were these soils well drained. On the other hand sandy, well-drained soils, such as the Gulf Coastal Plains, the oak, hickory, and pine uplands, and the rocky hillside types, will probably show a longer period of development than any other generalized type of soil. The semiarid region of Texas should show the longest period of weevil development under field conditions. The range in the developmental period at Madison, Fla., was from 16 to 38 days for weevils developing in squares and it appears probable that the maximum period would be much greater in the dry regions of Texas.

THE EFFECT OF THE DETERMINATE GROWTH OF THE COTTON PLANT ON THE BIOLOGY OF THE BOLL WEEVIL.

Perhaps no single factor contributes so much to the control of the weevil as the determinate growth of the cotton plant. On the Gulf Coastal Plains type of soil at Madison, Fla., the upland cotton usually sets its crop by the 20th of July and the cotton is practically all open by the 20th of August. In addition, the cotton plants are usually attacked by several species of rusts and wilts, which result in the plant becoming decadent, shedding off the leaves, squares, and immature bolls. This leaves the weevil with few breeding places. At this particular time also the weevils are so numerous in the cotton fields that the few squares growing on the plants are subjected to an overwhelming attack for both food and breeding purposes, which results disastrously to the fall generations of the boll weevil. The adult weevils in the field rapidly die off, and as few weevils are

hatching out the number that live to enter hibernation is greatly decreased. The cessation of squaring naturally forces a considerable number of weevils to attack bolls which otherwise might escape. Whether the loss resulting from this attack is offset by an advantage to the crop of the next season on account of the presence of fewer hibernated weevils has not been fully determined.

THE MAXIMUM NUMBER OF GENERATIONS OF THE BOLL WEEVIL UNDER FIELD CONDITIONS.

The number of generations of the boll weevil under field conditions varies with the different seasons and on the different types of soil. A very dry and hot season may affect either generation to such an extent that the eggs deposited during the first half of the generation may not produce weevils at all, and consequently the generation is much prolonged. The following table shows the maximum number of generations at Madison, Fla., under field conditions:

TABLE XVI.—*Maximum number of generations of the boll weevil bred in cotton squares, Madison, Fla.*

Generation.	Date.	Period from maturity to maturity.	Generation.	Date.	Period from maturity to maturity.
		Days.			*Days.*
First generation:			Fourth generation:		
Eggs deposited	June 1		Eggs deposited	Aug. 24	
Generation mature	June 22		Generation mature	Sept. 16	30
Second generation:			Fifth generation:		
Eggs deposited	June 30		Eggs deposited	Sept. 23	
Generation mature	July 20	29	Generation mature	Oct. 16	32
Third generation:			Sixth generation:		
Eggs deposited	July 28		Eggs deposited	Oct. 24	
Generation mature	Aug. 17	29	Generation mature	Nov. 17	33

The average date of killing frost at Madison, Fla., according to the 10-year average of the United States Weather Bureau, is November 29, therefore only six generations of weevils could develop under field conditions.

HIBERNATION OF THE BOLL WEEVIL IN FLORIDA.

During the winter of 1918–19 three series of hibernation experiments were conducted to determine the percentage of weevils surviving the winter at Madison, Fla. The experiments were arranged to secure data on the number of weevils surviving the winter in the open fields and along ditch banks, in the woods on the ground among the leaves and other rubbish, and in the moss covered trees in the woods (figs. 13, 14, 15).

Large wire screen cages 3 by 3 feet by 4 feet high were used for the hibernation experiments. The cages in the fields and on the ground in the woods were filled with an equal amount of moss, leaves, and cornstalks to represent approximately the material the weevils would hibernate in under normal conditions. The cages installed

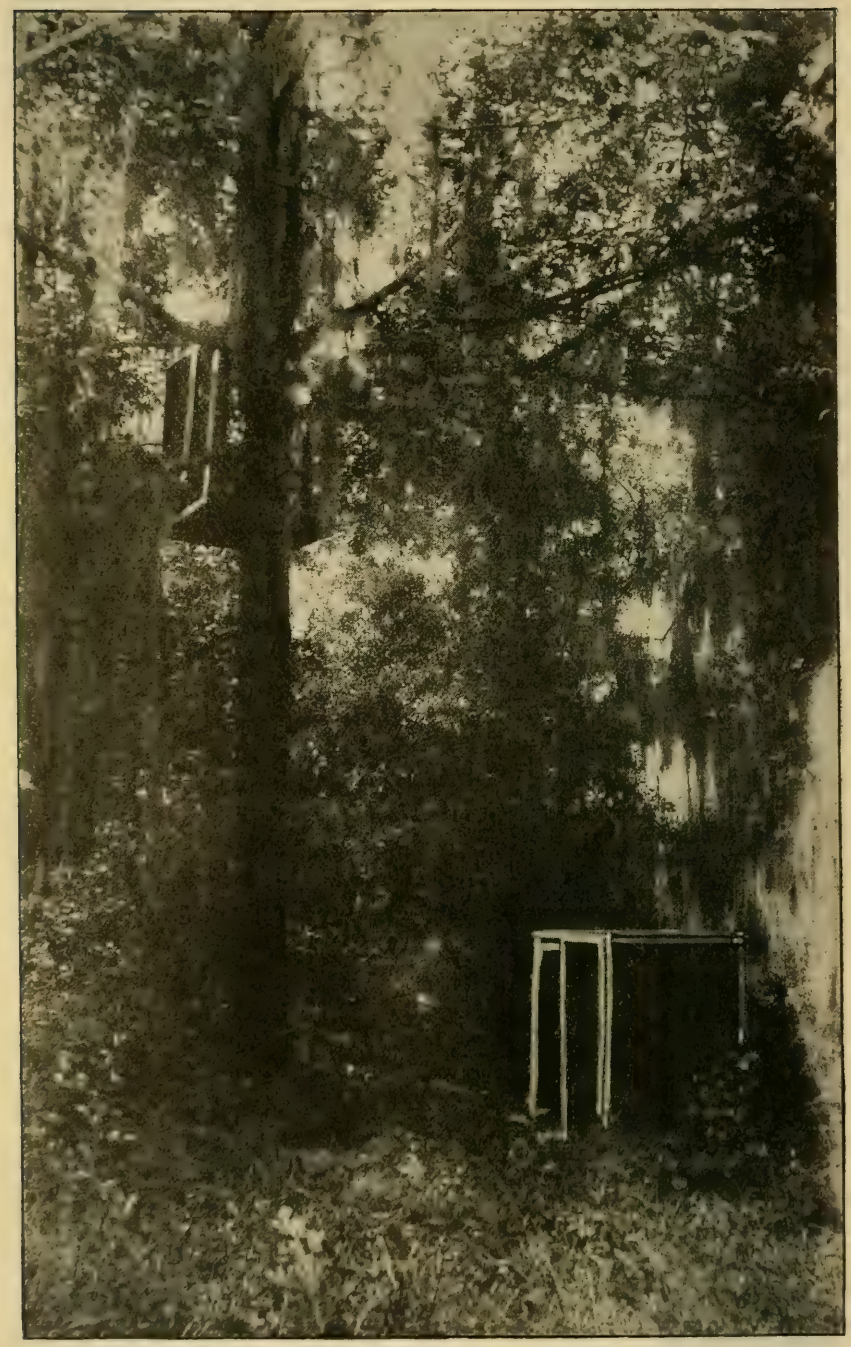

FIG. 13.—Hibernation cages on the ground in the woods, Madison, Fla.

in the trees were supplied with moss only and averaged 10 feet above the surface of the ground (fig. 15).

The boll weevils were collected from near-by cotton fields and installed in the cages every two weeks, beginning on October 1, the last cages being installed on December 1.

TIME OF ENTRANCE INTO HIBERNATION.

The time of entrance into hibernation by the boll weevil at Madison, Fla., usually begins about the time of the first killing frost. The average date of this event is November 29. During the fall of

FIG. 14.—Hibernation cages in the open field at Madison, Fla.

1918, however, the warm weather held on until about December 8. On November 13 the temperature dropped to 37° F., but the 20 days following this drop were extremely warm and all weevils seemed active until the drop in temperature on December 8. The weevils were in hibernation almost continuously until February 20, the date on which the emergence records were started. The mean temperature for November was 59.1° F. and 56.4° F. for December. When it is considered that hibernation begins between mean temperatures of 56 and 60° F. it is seen that the hibernation of the weevil in Florida during November and December is more of a drowsy condition than one of inactivity. The mean temperature for January, 1919, was 46.6° F. and for February 61.9° F. Therefore the weevil really entered hibernation late in December and remained in this condition for the month of January.

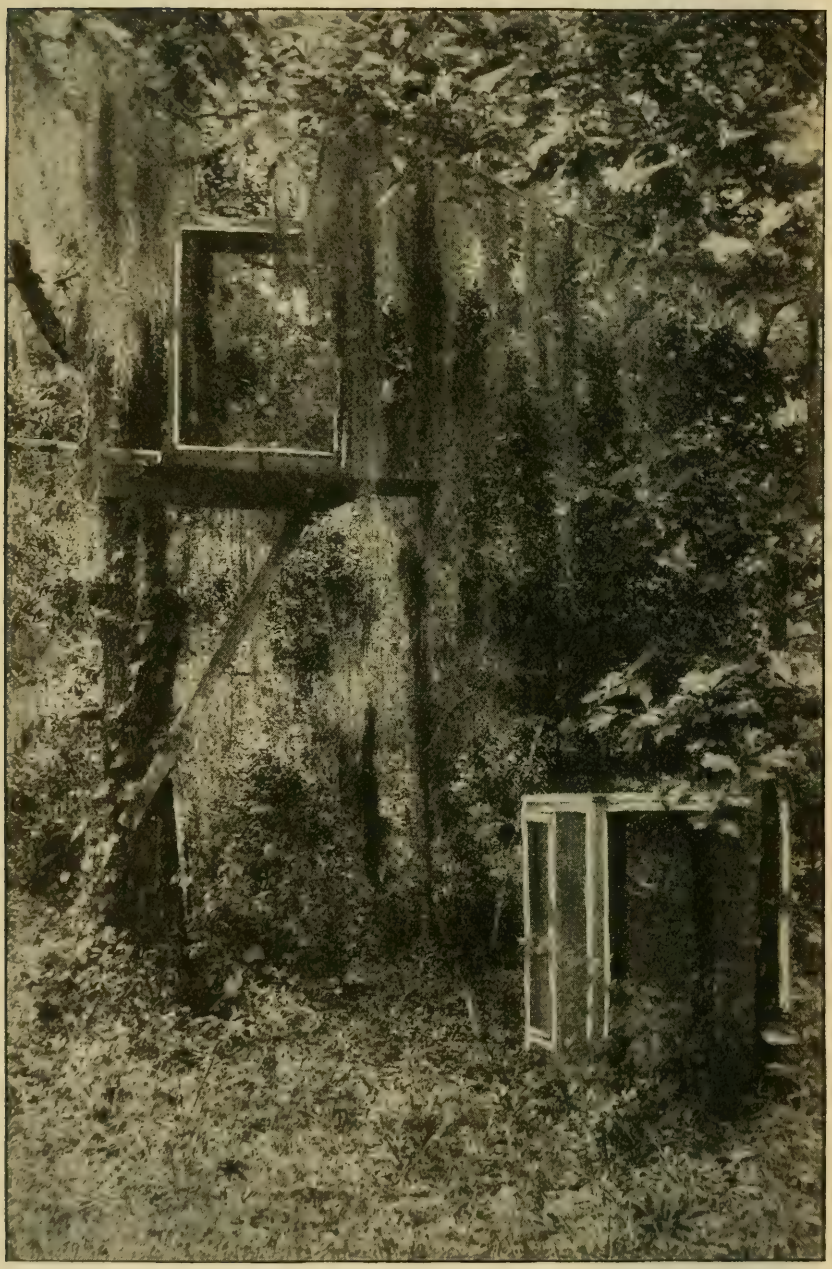

FIG. 15.—Hibernation cages 10 feet above ground in the trees at Madison, Fla.

ACTIVITY DURING THE HIBERNATION PERIOD.

In northern Florida the boll weevil, during the period of hibernation, is seldom inactive for a period of time longer than a month. As was pointed out, the only months in which the average mean temperature is below 56° F. are December and January, and even then it not infrequently happens that warm days occur such as would force the weevil to activity. Thus it might be said that the hibernation of the boll weevil in northern Florida is incomplete.

TIME OF EMERGENCE FROM HIBERNATION.

Owing to the incomplete hibernation of the boll weevil in northern Florida the time of emergence must necessarily be a variable date. February 20 has been selected as the date emergence started in the experimental work at Madison. However, six weevils emerged on the 10th of February and four on the 16th. After February 20 little cold weather is experienced at Madison, and this date may be safely assumed to represent approximately the date when emergence begins for weevils sheltered in places exposed to the direct rays of sunlight.

RATE OF EMERGENCE OF HIBERNATED WEEVILS IN FLORIDA.

The emergence period in Florida extended over the period from February 20 to July 7. The rate of emergence was decidedly more gradual than might be expected when the relatively high temperatures prevailing during March, April, and May are considered. The accompanying diagram (fig. 16) shows the daily rate of emergence of the weevil when hibernating in the open fields, on the ground in the woods, and in the moss on the trees 10 feet above ground. The diagram also shows three prominent periods of emergence, or rather accelerations in the rate of emergence—viz, March 3, April 4, and May 5, 6, and 7. On these dates the rainfall varied from 0.1 of an inch on March 3 to 1.75 inches on May 7. The extreme emergence recorded for May 6, 7, and 8 was also probably influenced by excessive temperatures. In the accompanying chart (fig. 17) the total percentage of rainfall compared to the total percentage of weevils emerged at different dates also indicates that excessive temperature was operating along with the rainfall after the 6th of May.

One of the interesting facts concerning the daily emergence of the weevil when hibernating under the three different conditions is that the emergence from the cages containing moss as hibernation quarters was much later than the emergence from the other two sets of cages. Spanish moss has been proven to be difficult to warm up sufficiently to force the weevils out of winter quarters before late in the season and the results at Madison, Fla., corroborate this fact in every way.

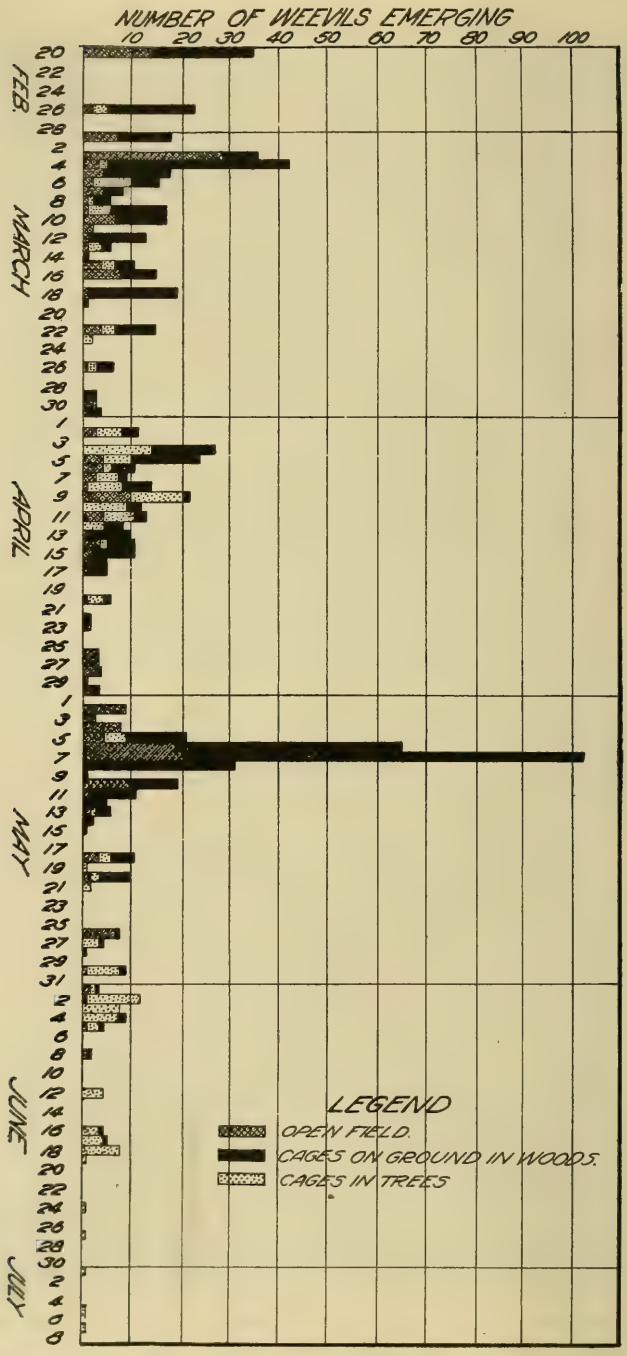

FIG. 16.—Showing the daily rate of emergence of the boll weevil when hibernating in the open field, on the ground in the woods, and in the moss-covered trees, Madison, Fla.

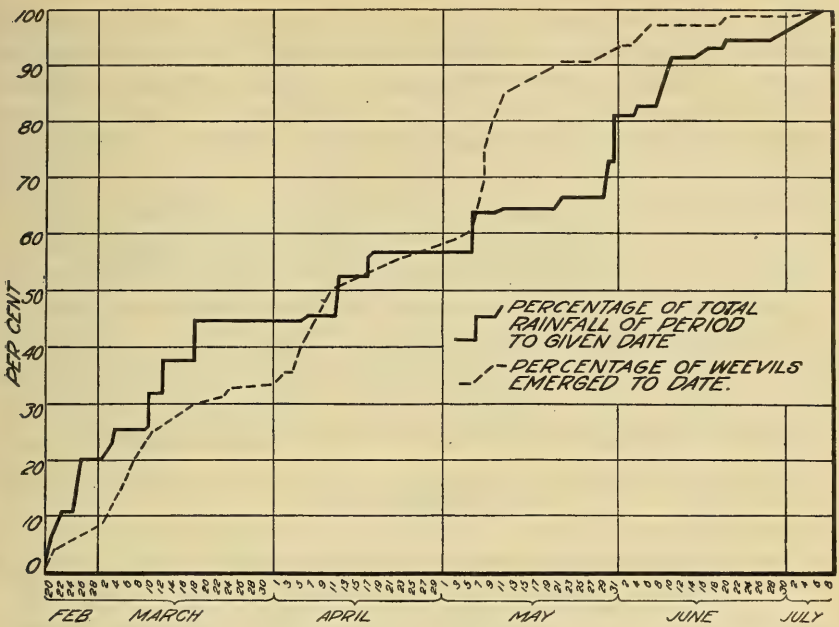

FIG. 17.—Showing the total percentage of rainfall compared with the total percentage of emergence of the boll weevil, Madison, Fla.

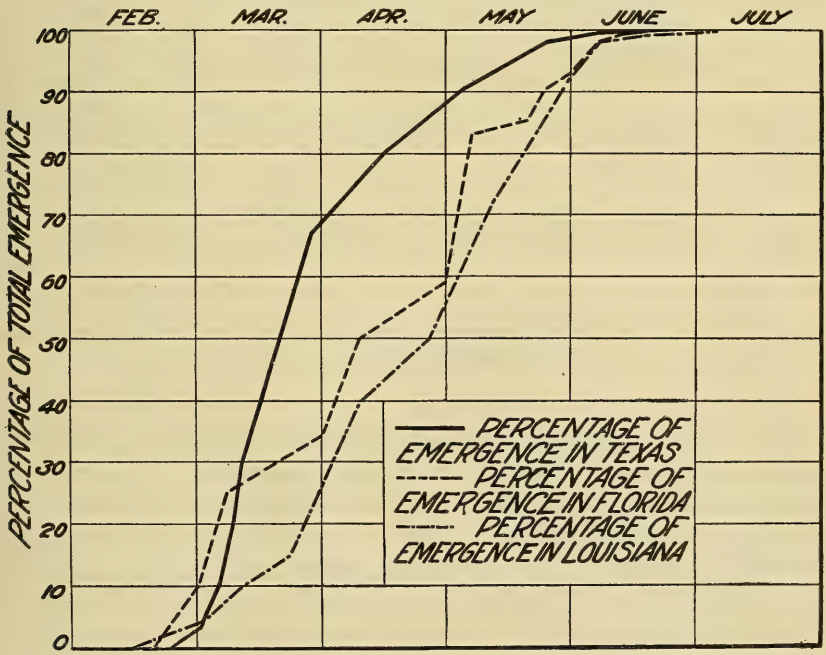

FIG. 18.—Illustrating the rate of emergence from hibernation of the boll weevil in Texas, Louisiana, and Florida.

The rate of emergence in Florida as compared to the rates of emergence in Louisiana and Texas is illustrated in the accompanying diagram (fig. 18). Twenty-five per cent of the boll weevils emerge in Florida a few days before the same percentage emerges in Texas and at least 20 days earlier than in Louisiana. The rate of emergence in Texas shows that 50 per cent of the weevils are out of hibernation approximately 20 days before 50 per cent are out in Florida. After 50 per cent of the weevils emerge the figure shows that the rate of emergence in Florida closely approximates the rate of emergence in Louisiana. This is to be expected since the hibernation shelter in Louisiana and Florida is decidedly more dense than the hibernation shelter found in Texas. Table XVII presents the records showing the percentage of total emergence of the boll weevil at different dates and places where hibernation experiments have been conducted.

TABLE XVII.—*Percentage of total emergence of boll weevils at different dates and at different places.*

Date.	Keatchie, La., 1906.	Tallulah, La.		Mansura, La.		Dallas, Tex.		Calvert, Tex., 1907.	Victoria, Tex., 1907.	Madison, Fla., 1919.
		1910.	1911.	1910.	1909.	1907.	1908.			
Feb. 21	0.00	0.31	36.95	1.64	7.20	0.00	0.00	0.00	0.00	3.6
Feb. 28	.00	.31	36.95	3.28	10.61	.00	.00	.00	12.01	5.03
Mar. 7	.00	6.62	39.92	10.56	19.22	24.48	7.27	22.80	27.92	21.9
Mar. 14	.00	10.09	63.83	15.69	19.73	36.36	23.63	31.90	48.23	30.2
Mar. 21	.00	13.56	70.35	21.19	23.24	57.14	45.45	44.30	66.24	34.2
Mar. 28	3.93	23.34	72.52	38.05	30.96	71.72	55.45	57.20	79.35	36.4
Apr. 4	6.87	35.95	74.69	46.53	38.16	75.70	63.63	64.20	84.16	41.4
Apr. 11	24.54	41.95	81.21	49.42	43.87	81.28	68.18	70.40	89.58	52.3
Apr. 18	32.11	46.05	87.73	52.41	47.78	84.46	74.54	77.40	93.80	57.7
Apr. 25	40.67	48.89	96.42	53.86	56.39	85.74	87.27	79.51	95.02	58.4
May 2	52.73	61.83	96.42	60.41	61.30	88.62	90.91	82.62	95.88	61.2
May 9	60.44	70.66	98.59	72.35	67.51	92.30	91.82	88.73	97.50	85.4
May 16	72.22	75.39	98.59	75.64	75.12	95.75	94.55	91.94	98.36	90.4
May 23	86.41	88.64	98.59	84.77	82.43	98.76	98.18	94.95	98.92	92.5
May 30	91.60	93.69	98.59	92.77	89.73	99.34	98.18	97.56	99.18	94.7
June 6	97.36	99.05	100.00	98.43	96.83	99.78	99.09	99.17	99.90	98.5
June 13	99.19	99.68	100.00	99.89	97.83	99.88	99.09	99.68	99.97	99.1
June 20	99.61	99.68	100.00	100.00	98.74	100.00	100.00	99.99	100.00	99.6
June 27	99.89	100.00	100.00	100.00	99.94	100.00	100.00	100.00	100.00	99.9
July 4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.9
July 7	.....	.....	.....	.....	.....	.....	.....	.....	.....	100.00

NUMBER OF BOLL WEEVILS SURVIVING THE WINTER WHEN HIBERNATING IN THE OPEN FIELD.

In Table XVIII are presented the data on the number of weevils surviving the winter when installed in the hibernation cages at different dates in the fall under open field conditions. Of a total of 4,300 weevils installed in the cages an average of 5.76 per cent survived the winter. The cage installed on November 15 showed the greatest percentage of the total emergence, while the cage installed on October 1 gave the smallest percentage of emergence. Emergence from hibernation started in all of the cages, except the one installed on December 1, on February 20. As was to be expected the date of

last emergence was made by a weevil placed in the hibernation cage on December 1. The dates on which 25, 50, and 75 per cent of the weevils had emerged follow very closely the sequence of installation.

TABLE XVIII.—*Hibernation of the boll weevil in open field cages, winter 1918–19.*

Cage No.	Date started.	Number of weevils installed.	Date of first emergence.	Date of last emergence.	Date on which 25 per cent had emerged.	Date on which 50 per cent had emerged.	Date on which 75 per cent had emerged.	Period of emergence	Number emerging.			Percentage of survival.
									Males	Females	Total.	
	1918.		1919.	1919.	1919.	1919.	1919.	*Days.*				
1	Oct. 1	1,000	Feb. 20	Mar. 16	Feb. 20	Feb. 20	Mar. 16	24	1	1	2	0.2
4	Oct. 15	1,000	...do...	May 27	Mar. 1	Mar. 8	Apr. 2	96	17	21	38	3.8
7	Nov. 1	1,000	...do...	June 2	Mar. 7	Apr. 2	May 6	102	23	22	45	4.5
10	Nov. 15	1,000	...do...	June 1	Mar. 16	Apr. 17	...do...	101	68	59	127	12.7
13	Dec. 1	300	Mar. 10	June 5	Apr. 11	May 4	May 10	87	14	9	23	7.6
Total		4,300	Feb. 20					410	123	112	235	
Av.		860						82	24.6	22.4	47	5.76
Max.		1,000						102	68	59	127	12.7
Min.		300						24	1	1	2	.2

NUMBER OF BOLL WEEVILS SURVIVING THE WINTER WHEN HIBERNATING ON THE GROUND IN THE WOODS.

Woods shelter has always been considered one of the ideal places for successful hibernation of the boll weevil. The results secured at Madison showed a total percentage of survival of 12.8 as compared to 5.76 per cent for the open field. The results of the woods hibernating experiments are presented in Table XIX. In every case the emergence started from the cages on February 20. The cage installed October 1 gave the smallest percentage of emergence (0.8), while the cage installed November 15 gave the highest emergence (20.7 per cent).

TABLE XIX.—*Hibernation records of adult boll weevils in cages on ground in woods.*

Cage No.	Date started.	Number of wevils installed.	Date of first emergence.	Date of last emergence.	Date on which 25 per cent had emerged.	Date on which 50 per cent had emerged.	Date on which 75 per cent had emerged.	Period of emergence	Number emerging.			Percentage of survival.
									Males	Females	Total.	
	1918.		1919.	1919.	1919.	1919.	1919.	*Days.*				
2	Oct. 1	1,000	Feb. 20	Apr. 2	Feb. 20	Feb. 26	Mar. 4	41	4	4	8	0.8
5	Oct. 15	1,000	.....do..	June 17	Mar. 4	Mar. 16	Apr. 5	117	19	22	41	4.1
8	Nov. 1	1,000	.....do..	June 1	Apr. 4	May 6	May 7	101	115	81	196	19.6
11	Nov. 15	1,000	.....do..	June 8	Mar. 5	Apr. 2	Apr. 28	108	113	94	207	20.7
14	Dec. 1	300	.....do..	June 16	Mar. 12	May 7	May 7	116	30	27	57	19.0
Total		4,300						483	281	228	509	
Av.		860						96.6	56.2	45.6	101.8	12.8
Max.		1,000						117	115	94	207	20.7
Min.		300						41	4	4	8	0.8

NUMBER OF BOLL WEEVILS SURVIVING THE WINTER WHEN HIBERNATING IN SPANISH MOSS 10 FEET ABOVE GROUND.

The data on the survival of the weevils in cages installed 10 feet above ground in trees are presented in Table XX. Only 4.54 per cent of the 4,400 weevils installed in the cages in the trees survived the winter. The cage installed on November 15, however, gave a total emergence of 10.2 per cent. In connection with the dates of the beginning of emergence of the hibernated weevils it is interesting to note the manner in which the moss held back the weevils, the first emergence not occurring before February 26, and the last emergence taking place on July 7.

TABLE XX.—*Hibernation record of boll weevils in cages installed in the trees.*

Cage No.	Date installed.	Number of weevils in cage.	Date of first emergence.	Date of last emergence.	Date on which 25 per cent had emerged.	Date on which 50 per cent had emerged.	Date on which 75 per cent had emerged.	Period of emergence.	Number emerged.			Height above ground.	Per cent of survival.
									Males.	Females.	Total.		
	1918.		1919.	1919.	1919.	1919.	1919.	*Days*					
3	Oct. 1	1,000	.....	.....	.....	.....	.....	0	0	0	0	10	0
6	Oct. 15	1,000	Mar. 3	July 1	Apr. 2	Apr. 9	Apr. 14	106	33	27	60	10	6.0
9	Nov. 1	1,000	Mar. 6	July 7	May 10	June 2	June 4	113	20	18	38	10	3.8
12	Nov. 15	1,000	Mar. 4	July 5	Apr. 7	May 5	June 2	112	60	42	102	10	10.2
15	Dec. 1	400	Feb. 26	May 20	Feb. 26	Mar. 8	May 4	83	6	5	11	10	2.7
Total	.....	4,400	.....	.....	.....	.....	.....	414	119	92	211	50	.....
Av	.....	880	.....	.....	.....	.....	.....	82.8	23.8	18.4	42.2	10	4.54
Max	.....	1,000	.....	.....	.....	.....	.....	113	60	42	102	10	10.2
Min	.....	400	.....	.....	.....	.....	.....	83	0	0	0	10	0

SUMMARY OF THE HIBERNATION OF THE BOLL WEEVIL UNDER ALL CONDITIONS, WINTER 1918–19.

Table XXI gives a summary of the hibernation records secured at Madison, Fla., during the winter 1918–19. The records show that of 13,100 weevils installed in the three sets of hibernation cages at different dates during the fall of 1918, only an average of 7.54 per cent survived the winter. The highest percentage of survival is shown in the cages installed in the woods on the ground. The second highest percentage of survival was in cages installed in the open field and the lowest percentage of survival in the cages installed 10 feet above the ground. It is also noticeable that in every case weevils placed in the hibernation cages on November 15 survived in greater numbers than those placed in the cages at an earlier or later date. It is evident that weevils that become adult right at the time of entrance into hibernation are not in as good physical condition to go through the winter as weevils that have had time to feed longer and thus get their stomach contents in proper condition for entering hibernation. The maximum survival by the weevils that were placed

in the hibernation cages on November 15 was followed in order of total emergence by the survival of weevils placed in the cages November 1 and December 1, respectively.

TABLE XXI.—*Summary of hibernation of Anthonomus grandis under all conditions—winter 1918–19.*

Date started.	Total number of weevils placed in cages.	Open field.			On ground in woods.			In trees in woods.			Total number weevils emerged.		Total percentage surviving winter.
		Number emerged.		Percentage surviving winter.	Number emerged.		Percentage surviving winter.	Number emerged.		Percentage surviving winter.			
		Males.	Females.		Males.	Females.		Males.	Females		Males.	Females.	
1918.													
Oct. 1...	3,000	1	1	0.2	4	4	0.8	0	0	0	5	5	0.3
Oct. 16..	3,000	17	21	3.8	19	22	4.1	33	27	60	69	70	4.6
Nov. 1...	3,000	23	22	4.5	115	81	19.6	20	18	3.8	158	121	9.3
Nov. 15..	3,000	68	59	12.7	113	94	20.7	60	42	10.2	241	195	14.5
Dec. 1...	1,100	14	9	7.6	30	27	19.0	6	5	2.7	50	41	9.0
Total..	13,100	123	112	.....	281	228	.....	119	92	.....	523	432	.....
Av....	.....	24.6	22.4	5.76	56.2	45.6	12.8	23.8	18.4	15.34	104.6	86.4	7.54
Max...	.....	68	59	12.7	115	94	20.7	60	42	60	241	195	14.5
Min...	.....	1	1	0.2	4	4	0.8	6	5	0	5	5	0.3

GENERAL SUMMARY.

At Madison, Fla., the average longevity of hibernated weevils without food was 12.7 days, and 18.8 days when fed on cotton plantlets. Adult weevils of the first and second generations lived 24.3 days on cotton squares and 12.3 days on cotton bolls.

On sea-island cotton plantlets the hibernated weevils lived 11.05 days. The first and second generation weevils fed on sea-island cotton squares lived 10.7 days, while the weevils fed on sea-island cotton bolls lived only 15.3 days.

There is practically no difference in the longevity of boll weevils on sea-island and upland cottons.

The average period from the time the weevils become adult to oviposition at Madison, Fla., for all experiments, was 8.9 days for weevils bred under insectary conditions and 7.07 days for weevils bred under field conditions.

The average period of oviposition under insectary conditions for all weevils under observation on upland cotton was 33.1 days. The entire series deposited eggs over an average period of 31.7 days on sea-island cotton. The largest number of eggs deposited by a single female weevil was 432. This record was made by a hibernated female on upland cotton squares under insectary conditions. The largest number of eggs deposited during any one day under insectary conditions was 25. This record was also made by a hibernated female weevil.

The average period from oviposition to adult of all weevils bred under insectary conditions on upland cotton squares was 14.91 days. On sea-island cotton the average period from egg to adult for all weevils bred under insectary conditions was 14.94 days.

The field-bred weevils showed more vitality than weevils bred under artificial conditions.

Under field conditions the average length of time the infested squares hung on the upland cotton plants after egg puncture was 11.5 days. The time required to complete the development of the immature weevil after the infested square dropped to the ground was 10.8 days in upland cotton squares.

There was practically no difference shown in the length of the developmental period of the boll weevils bred in short-staple upland, long-staple upland, and sea-island cotton squares.

The developmental period of the boll weevil was approximately 7.5 days longer under field conditions than under insectary conditions at Madison, Fla.

Soil temperatures of 120° F. and higher are usually fatal to the immature weevils under field conditions.

The boll weevil at Madison, Fla., shows a decided tendency to form a new variety.

The hibernation of the weevil at Madison, Fla., is incomplete and the adults are seldom inactive more than 30 days at a time.

The emergence from hibernation of the weevil in Florida is very gradual, the total daily emergence bearing a direct relation to the total daily rainfall.

Weevils survived the winter in larger numbers in cages set on the ground in the woods than in the open field or in cages in trees 10 feet above ground. Weevils placed in hibernation cages on November 15 survived in larger numbers than on any other date of installation.

The percentage of total emergence from hibernation begins with more acceleration in Florida than in Texas up to the time that 25 per cent emerges. After 25 per cent of the weevils have emerged in Florida the emergence is less rapid and the Florida emergence curve very closely approaches the emergence curve for Louisiana.

The total percentage of hibernating weevils that survived the winter of 1918–19 at Madison, Fla., was 7.54.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 927

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ April 16, 1921

COMMERCIAL UTILIZATION OF WASTE SEED FROM THE TOMATO PULPING INDUSTRY.

By J. H. Shrader, formerly *Chemical Technologist*, and Frank Rabak, *Chemical Biologist, Office of Drug, Poisonous, and Oil-Plant Investigations.*

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PROFITABLE UTILIZATION OF WASTE MATERIALS.

The utilization of waste materials from the canning or packing of certain classes of agricultural products is at present commanding considerable attention in connection with the possibility of reducing the waste of commodities of commercial importance. The nature of the waste material varies, of course, with the type of products which are canned or packed.

In the manufacture of the various tomato products for which there are very extensive packing operations in the United States there occurs a waste, consisting of seeds and skins, which possesses inherent possibilities from the standpoint of profitable utilization.[1] At present this material is not being utilized, possibly because of lack of knowledge regarding the proper methods of procedure attending a well-directed commercial project of this character, and

[1] Rabak, Frank. The utilization of waste tomato seeds and skins. U. S. Dept. Agr. Bul. 632. 15 p. 1917.

possibly also because of lack of information bearing on the probable returns. These are important factors which underlie the establishment of an industry of this kind and will be given careful consideration in this bulletin.

NATURE AND SOURCE OF TOMATO WASTE.

The largest proportion of waste which accumulates in the tomato-packing industry results from the pulping operations connected with the manufacture of catsup, pulp, soup, paste, and sauce. The waste as it occurs in these pulping plants consists of a wet mass of seeds and skins (fig. 1). Only the seeds, however, will here be considered,

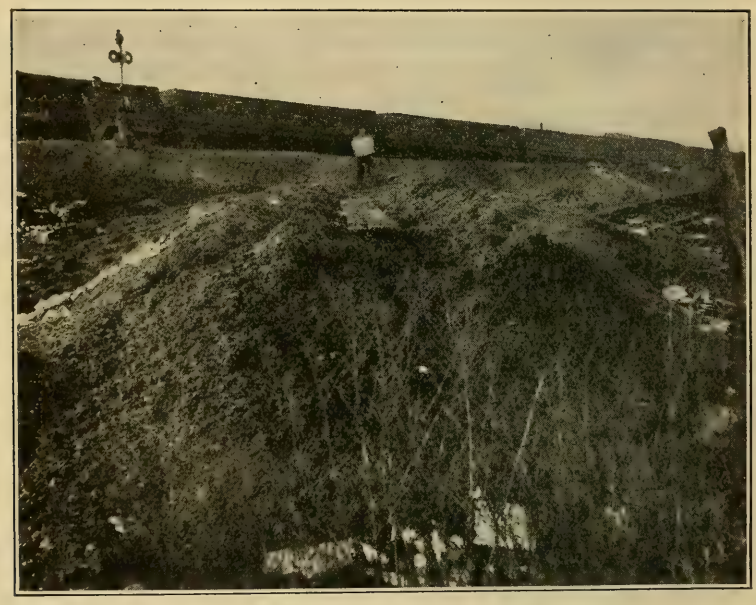

FIG. 1.—Tomato-seed waste at a pulping plant.

since this is the portion which possesses the greatest value as a source of commercial products.

DISTRIBUTION AND QUANTITY OF TOMATOES PULPED ANNUALLY.

The tomato pulping stations are scattered over a large area, including Maryland, Delaware, New Jersey, New York, Ohio, and Indiana. Since these States comprise a continuous geographical series, the investigation has been restricted entirely to this area.

In this connection it may be of interest to point out the size of tomato pulping stations. Because of the perishable character of the raw material it is necessary that the stations be located in tomato-growing localities, in order that only a minimum period of time may

elapse between the picking of the fruit and the preparation of the products. This has led to the erection of a number of pulping stations, most of which are comparatively small from the standpoint of seed produced. A station which pulps 5,000 baskets (of five-eighths of a bushel each) of tomatoes in a 10-hour day is considered a large plant. Many, however, handle only 1,000 baskets. Thus, it is evident that any utilization project must be concerned with the larger stations located at readily accessible points.

Approximately 205,000 tons of tomatoes are pulped annually at the larger stations in what might be called the eastern and middle-western tomato belts, distributed by States as shown in Table I.

TABLE I.—*Distribution and quantity of tomatoes pulped annually at the larger pulping stations, with the tonnage of dry seed produced.*

State.	Estimated product (tons).		State.	Estimated product (tons).	
	Tomatoes pulped.	Waste seed.		Tomatoes pulped.	Waste seed.
Delaware	6,600	33	New Jersey	63,000	315
Illinois	12,300	61	New York	10,000	50
Indiana	69,000	345	Ohio	8,000	40
Kentucky	948	5	Pennsylvania	7,400	37
Maryland	26,100	130			
Michigan	2,000	10	Total	205,528	1,026

The quantity of seed obtainable from raw tomatoes was ascertained in connection with field work carried on in different parts of the country and from reports of firms now operating on seed recovery, thus eliminating the uncertainty of estimates as to the tonnage of waste seed available. From determinations made with Maryland fruit it was found that seed reduced to a 10 per cent moisture basis constituted about 0.6 per cent of the normal tomatoes. Other determinations on middle-western tomatoes showed from 0.4 to 0.5 per cent. Firms operating on seed recovery for planting purposes report about 0.58 per cent. One-half of 1 per cent has, therefore, been adopted as representing the average percentage of seed available. Hence, each ton of tomatoes pulped should yield about 10 pounds of dry seed. These figures, of course, refer to seed practically free from skins, with a moisture content of 10 per cent, such as would be produced commercially by the recovery methods to be described later.

Table II records the tonnage of tomatoes pulped over a period of five years, 1914 to 1918, inclusive, only the data actually reported being included. The figures, as here given, refer to the larger pulping stations, situated at points readily accessible for railroad transportation. Figures from the smaller producing stations have not been included, because of the increased cost which would be involved in assembling small quantities of material.

TABLE II.—*Quantity of tomatoes pulped from 1914 to 1918, inclusive, in the larger plants in the eastern and middle-western tomato belts.*

State.	Production (tons).				
	1914	1915	1916	1917	1918
Delaware	450	1,550	4,650	6,540	5,050
Illinois		3,200	11,300	11,300	10,600
Indiana	13,677	11,637	19,736	22,837	46,077
Kentucky			1,000	878	967
Maryland	6,000	5,300	7,556	29,489	29,165
New Jersey	12,681	9,338	14,570	16,362	19,323
New York	12,800	7,636	10,215	5,962	14,093
Ohio	12,689	12,674	9,412	4,639	9,961
Pennsylvania	10,400	5,500	9,000	4,040	4,949
Total	68,697	56,835	87,439	102,047	140,185

Supplementing the figures given in Tables I and II, there is presented in Table III the entire production of tomatoes for soups, pulp, purees, etc., in two years, 1917 and 1918, as published by the Bureau of Crop Estimates on January 17, 1919.

TABLE III.—*Quantity of tomatoes used for soups, pulp, purees, etc., in the eastern and middle-western tomato belts for the years 1917 and 1918.*

State.	Total production (tons).		State.	Total production (tons).	
	1917	1918		1917	1918
Delaware	14,564	37,870	New Jersey	69,461	110,209
Illinois	3,137	7,494	New York	10,531	37,880
Indiana	60,947	148,225	Ohio	10,531	25,001
Kentucky	2,017	4,309	Pennsylvania	3,362	8,024
Maryland	19,083	26,083			
Michigan	3,137	7,515	Total	187,770	412,610

QUANTITY OF SEED AVAILABLE.

Since one-half of 1 per cent is adopted as the yield of dry seed from whole ripe tomatoes, the total quantity available, as shown in Table I, is 1,026 tons. This tonnage is based on the output of pulp from only the largest manufacturers in the States specified. By calculation from the figures given in Table III for 1918, it is found that a total of 2,063 tons of seed is available as the output of all the pulping plants in the eastern and middle-western tomato belts.

COMMERCIAL PRODUCTS OBTAINABLE FROM TOMATO SEED.

By proper treatment tomato seeds may be made to yield two important commercial products—namely, fixed oil and press cake, or meal. In order to obtain these products it is necessary that a certain procedure be followed, and the purpose of this bulletin is to describe in detail the handling of the material from the time the wet waste

leaves the pulping machine until the finished product is ready for the market. The accompanying diagram (fig. 2) shows the reduction of waste from the tomato pulping industry.

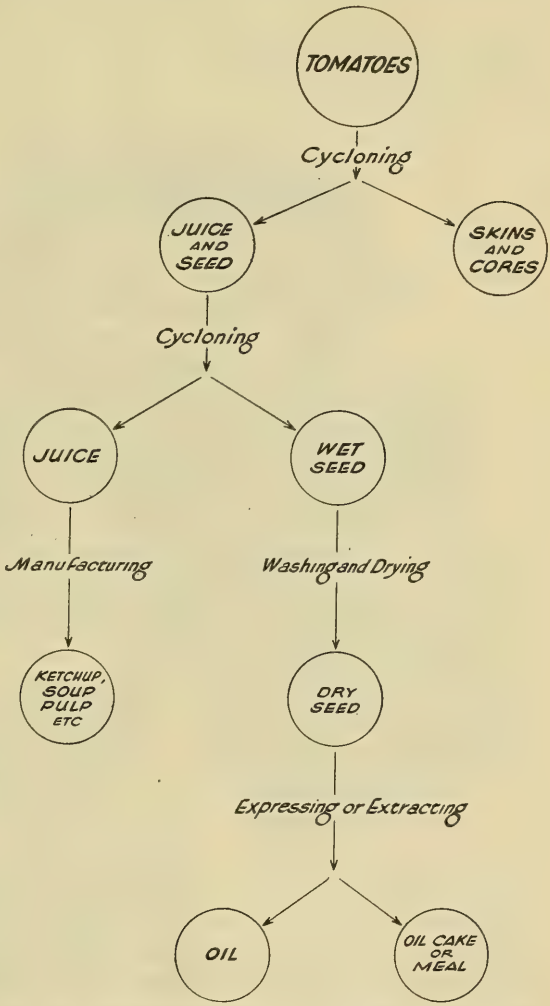

FIG. 2.—Diagram showing the reduction of waste from the tomato pulping industry.

PROCEDURE IN HANDLING TOMATO WASTE.

Two important steps are involved in preparing tomato seed for oil production: The separation of the seed from the wet waste material and the drying of the seed.

SEPARATING THE SEED FROM THE WASTE MATERIAL.

The wet mass of seeds and skins as it comes from the pulping operations is known as "cyclone waste,"[2] and several methods may be employed for separating the seeds from this waste. The common practice where only small quantities of seed intended for planting purposes are involved consists in suspending the waste in several volumes of water and agitating the mass. The skins, being lighter than the seed, have a tendency to float, while the seeds and cores sink.

In large-scale operations[3] the waste is discharged into a long trough provided with a false bottom, the mesh of which is of a size which

[2] So called from the name of the pulping machine.

[3] Huelsen [W. A,] Tomato-seed experiment. *In* The Canner, v. 47, no. 24 (no. 1246), p. 42. 1918

allows only the seed to fall through. A slow stream of water enters the trough at the upper end and overflows at the lower end. The waste is continuously introduced with the water, thoroughly agitated with it, and carried slowly forward. In this movement the mass becomes disintegrated, allowing the seed to settle slowly, while the skins are carried forward and discharged by the overflow or skimmed off by workmen. When the seed accumulates above a certain point in the trough the operation is discontinued and the trough dumped. The seed is then placed in muslin bags and centrifuged for about half an hour, to remove the excess moisture, and then dried. One disadvantage of this method lies in the fact that it requires the entire time of several workmen. Such practice pays when the seed is intended for planting purposes, in which case it brings a comparatively high price, but if intended for crushing for oil it is not profitable.

Another method which has been developed on a commercial scale consists in dumping the waste into a large funnel-shaped receiver, 4 to 5 feet in diameter at the top and possibly as deep, filled with water which has been given a circulatory motion by impinging several streams of water set at small angles to the surface. As it is dumped into the vessel the waste is disintegrated by the swirling motion. The seeds sink, while the skins are carried over the top in a continuous overflow. When a large quantity of seed has accumulated the action is stopped, the vessel tilted, and the excess water poured off. The container is then restored to its original position and the seed dumped by a gate valve in the bottom. It is estimated that by this method about 90 per cent of the seed is recovered. Two men operate the entire recovery equipment, including the seed separation and the drying units. Such a machine is large enough to handle all the waste from a 5,000-basket plant.

In Italy the waste is first dried and the seed then fanned out. The advantage of this method is that the seed is rendered available by one operation. The disadvantage, however, is that some of the seeds are lost because, in drying, the particles of skin curl back and inclose many of them. It is not believed that any amount of grinding and fanning can recover all or nearly all the seed, although no figures are available as to the efficiency of such operations.

The most practical method for separating the seed from the waste is to make the separation in the original cycloning operation used in making the pulp, thus entailing only one handling. The operation is continuous, with no intermittent discharge and with no extra labor. To all who operate the ordinary cyclone pulping machines (fig. 3) it is apparent that if the perforations of the screen are just large enough to permit the passage of the seeds, these with the pulp will flow out of the machine in a continuous stream, while the cores and skins will be discharged through the gate of the machine as usual.

A 5-mesh woven screen made of No. 12 wire has been found very satisfactory. There is a greater tendency for the small pieces of skin to go through the meshes with the seed than for the seed to remain back with the skins; in other words, the operation is in favor of the seed. The stream of pulp and seed is pumped into an adjoining cyclone provided with an ordinary breaker screen (about 20-mesh), the perforations of which are too small to permit the passage of the seed. The pulp or juice then flows out in a continuous stream, while the seeds pass out through the gate. Inasmuch as the two machines are placed together, preferably one behind the other, and one man operates both, it follows that this operation necessitates practically no increase in labor and is continuous and efficient. Experience with this method for more than two seasons at the Arlington Experimental Farm near Washington, D. C., confirms the conclusions as to its effectiveness.

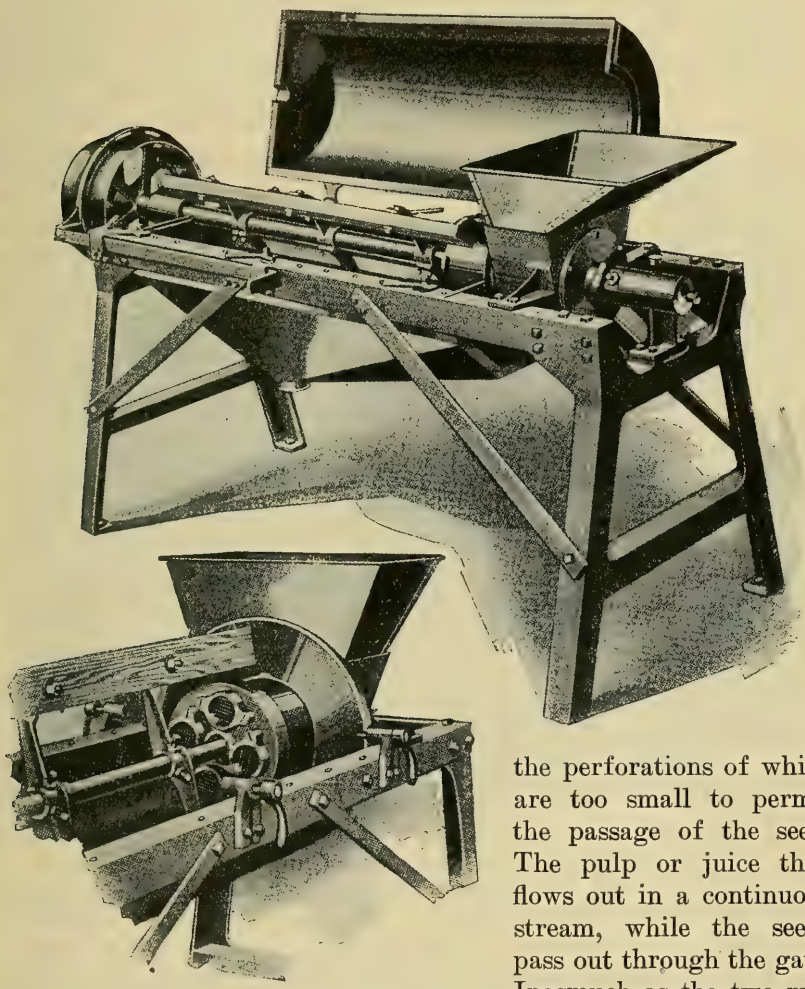

FIG. 3.—A cyclone pulping machine.

A double cyclone is now being manufactured which separates the seeds from the skins and cores in one operation.

DRYING THE SEED.

Before the seed obtained from the operations just described is in condition for drying, it is preferable that it be washed and the excess moisture removed. As the seed emerges from the cyclone it is covered with a mucilaginous, slimy coating, and when placed in rotary driers in this condition it sticks to the drying surfaces. This coating also prevents satisfactory treatment in the preliminary removal of water. It has been found that satisfactory washing can be accomplished by suspending the seed in a stream of hot water and cycloning it out of the mixture by using the ordinary breaker cyclones. In practice this washing is done as follows: The seed is thrown into a funnel set in the inlet part of a centrifugal pump, while a stream of hot water, likewise directed into the funnel, carries the seed with it down into the pump, where the churning action of the rotor breaks up the clumps of seed, suspending each particle separately and discharging the whole mass more or less homogeneously into the washing cyclone. The seed is discharged through the gate quite clean and bright.

Cyclone waste as it is usually produced contains about 80 per cent of water, while the seed contains from 65 to 70 per cent. One difficulty in drying material with such a high moisture content is the cost of the operation. To economize in this respect and at the same time shorten the period of drying, several methods of moisture reduction may be employed.

A considerable proportion of the excess moisture can be removed by pressure. For this purpose small hydraulic presses of the type used for pressing out apple or grape juice may be used. Cloths are laid on racks, the seed is placed thereon, and the edges of the cloths are folded over, thus forming a cake. Several of these, one above the other, are placed in the press and hydraulic pressure applied. From 10 to 15 per cent of moisture can be removed by such treatment. A small press may have a capacity of about 400 pounds of wet seed an hour.

Moisture reduction by centrifuging has also been tried. In this method[4] the seed is placed in a bag and whirled, as in the ordinary type of laundry centrifuge. The use of a bag prevents the packing of the seed in the machine and facilitates emptying. The moisture content of seed, which originally was about 55 per cent, was found to be reduced to about 51 per cent. A centrifuge of ordinary size (about 3 feet) will handle approximately 600 pounds of seed an hour,

[4] Huelsen [W. A.], 1918. Op. cit., p. 42.

depending, of course, on the size and duration of the cycle. It will be noted that the above methods are not continuous and that they require the entire attention of the operator.

A moisture expeller (figs. 4 and 5) has been successfully applied in this operation. The machine is essentially similar to an oil expeller, consisting of a horizontal barrel composed of bars bolted together, along the longitudinal axis of which rotates a screw. This latter carriers the charge of wet seed forward and discharges it over a cone in the outlet of the barrel. By adjusting this cone in the throat of the barrel the degree of pressure, and consequently the extent of moisture reduction, can be regulated.

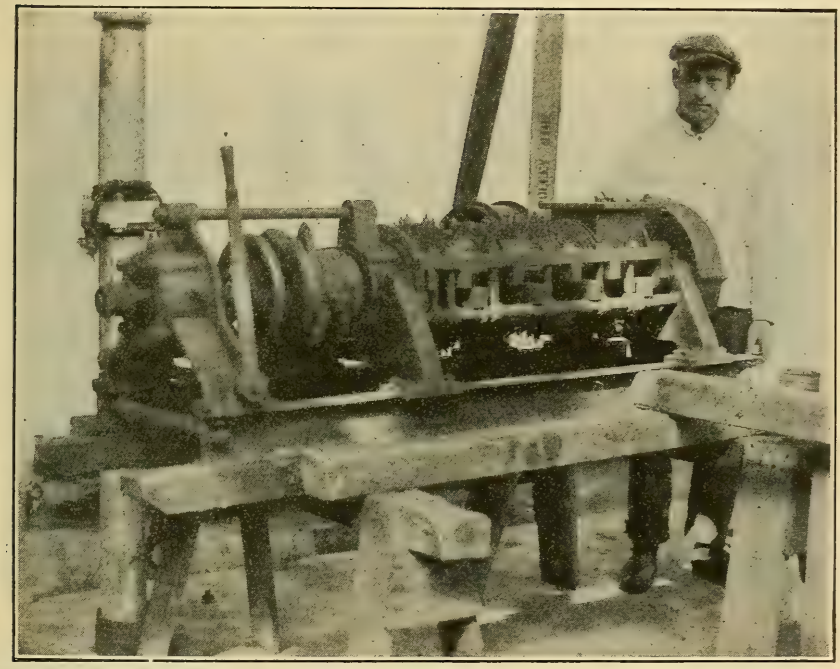

FIG. 4.—An experimental moisture expeller; Closed.

The machine does not operate on unwashed seed, as the slippery character of the latter causes it merely to churn. It is absolutely necessary that the seed be denuded of this coating material, and preferably pressed hot. All of this can be accomplished, of course, by washing the seed in hot water and pressing it immediately. By such procedure the moisture content can be reduced from 65 to about 52 per cent. The operation is continuous and does not need the constant attention of the operator; in fact, after being adjusted at the beginning of the run it operates without further change, except possibly a slight adjustment from time to time because of the varying character of the seed. Among its other advantages is the fact that owing

to the spongy character of the seed it emerges from the machine in a light, puffy condition, which obviates the necessity for grinding. Expellers of this type are manufactured in three commercial sizes, handling 400, 800, and 1,600 pounds of raw material an hour, with a power consumption of 5, 7½, and 10 horsepower, respectively. Many of the seeds are bruised and torn, which would render them unsatisfactory for planting purposes, but the operation is quite satisfactory for reducing the moisture in seed intended for oil, because for this purpose such bruising is immaterial.

Drying is one of the most important processes in the successful and economical handling of the seed. Various types of machines for this operation are on the market. These may be classed under two general heads, tray driers and rotary driers.

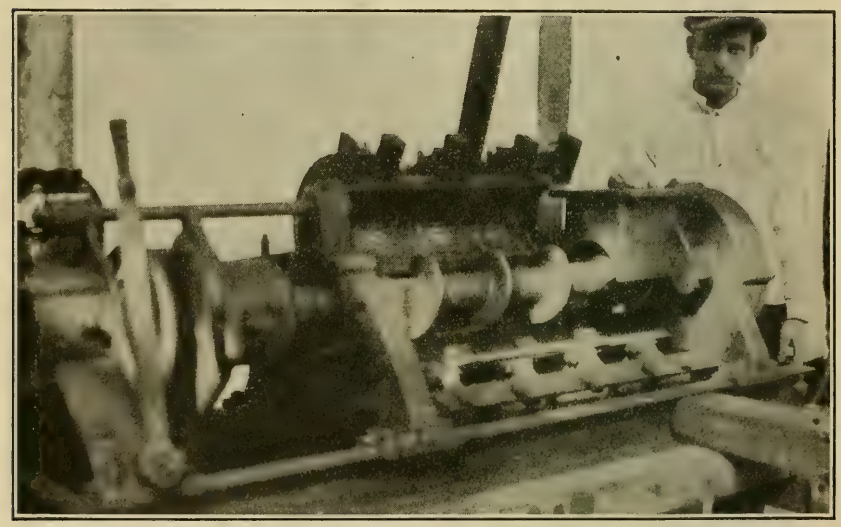

FIG. 5.—An experimental moisture expeller: Open.

The tray drier is most frequently employed for drying tomato seed intended for planting purposes. The seed, freed from as much water as can readily be drained off or as can be removed by slight pressure in some form of press, is spread out on trays in layers approximately one-half to 1 inch in depth and subjected to a slow current of warm air. In some cases no artificial heat whatever is imparted to the air current, the lack of heat being made up by greatly increasing the volume of air passed over the seed, which is protected from being blown away by placing a screen over the layers.

It is claimed that this treatment insures a high percentage of germination and is therefore perfectly feasible when the seed is intended for planting purposes; but for seed intended for oil extraction it is too expensive, since it involves a greater initial cost for

equipment because of the necessarily increased size of the air blower and the consequent power required for operating it.

A drier which can be satisfactorily used for handling tomato seed for oil extraction is a tunnel drier described in Farmers' Bulletin 984, United States Department of Agriculture (fig. 6). An adaptation of this form of drier for handling the quantities of seed produced by a plant pulping 1,000 baskets of tomatoes a day is a rectangular box 10 feet long, 2 feet wide, and 6 feet high. One end rests upon the floor (fig. 6, left), and the other end is raised 2½ feet above the floor level by increasing the length of the studding. This gives the floor and ceiling of the box a uniform slope of 3 inches per foot of

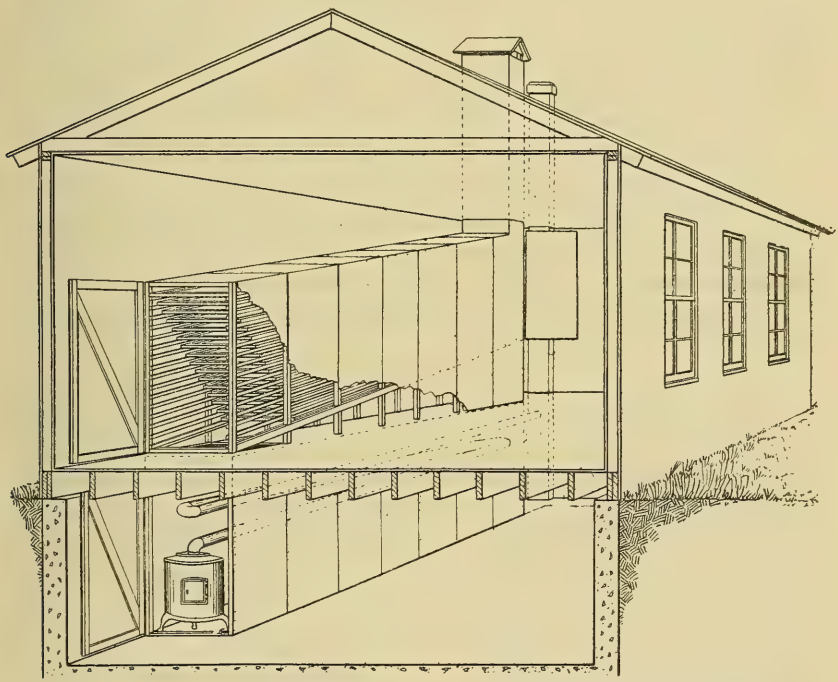

FIG. 6.—A 1-tunnel evaporator.

length. The box has a solid floor except at the lower end, where there is an opening 3 by 2 feet which permits the entrance of warm air from the furnace placed immediately below the opening. A ventilating shaft 2 by 3 feet is placed at the upper end and extends through the roof to a height well above the top of the chimney and the peak of the roof.

The runways carrying the trays are made of strips 1 by 1 inch or 1 by 2 inches, nailed 4 inches apart to the studding on centers, thus accommodating 16 tiers of trays, one above another. The trays may be 2 by 3 feet or 2 by 4 feet, made of wire mosquito netting nailed to frames made of wooden strips 1 by 1 inch.

The trays of freshly prepared material are placed in the drier at the upper and cooler end and are gradually pushed toward the lower and hotter end as they become partially dried. When the drier is filled the edge of the tray on the lowest runway is placed flush with the edge of the hot-air opening, the next tray above projects about 2½ inches over it, and so on to the top, as shown in figure 6. The arrangement at the opposite end is, of course, exactly the reverse. When thus arranged the edges of the trays act as baffle boards, breaking up the column of hot air arising through the floor and forcing it to pass between the successive tiers of trays. Any good-sized strongly constructed stove and any fuel which is available may be used. The arrangement of the pipe, as shown in the drawing, permits the maximum use of the heat produced by the fuel burned. The stove room may be temporarily partitioned off by walls of rough boards. Instead of a stove, a coil of steam pipe may be used for heating. The walls, floor, and ceiling of the drier may be of matched flooring, siding, sheet iron, or beaver board.

A drier of the size shown will provide a little more than 300 square feet of drying space and will accommodate approximately 700 pounds of wet seed at one charge. If all the wet seed which is produced in one day is left in such a drier overnight it will be dry the following morning. It is estimated that the entire cost of such a drier will not exceed $250.

The Bureau of Chemistry has developed and successfully applied the so-called trayless drier (fig. 7) to the drying of vegetable products. This drier consists of a tight wooden box in which a double series of dumping trays is mounted. The total drying area, consisting of 32 square feet, is divided into four compartments, 1 foot wide and 4 feet long, each being provided with two dumping trays, as shown in the illustration. The drier is made of white pine lined with compo board to prevent the leakage of air. The lower front of the drier is fitted with two doors, through which the finished material can be removed. The air is heated by a furnace and is supplied directly by a blower fan which delivers about 2,000 cubic feet of air a minute against a static pressure of a 1-inch water gauge. A furnace, such as is used for heating houses, is large enough for a drier of the size described. Where steam is available steam coils can be used for heating. Devices for charging the drier or for discharging the finished material are not shown, but could easily be constructed, thereby making the operation more or less automatic. The lower compartment could be made hopper shaped and fitted with a gate valve discharging the seed to a conveyor or oscillating apron. In operation the wet material is placed in the upper tray for about half an hour. The tray is then tilted and the charge is dumped to the tray below and a fresh charge put into the

upper tray. When the seed in the lower tray is dry the latter is tilted and the batch dumped into the hopper bottom. This process is then repeated.

This drier will satisfactorily dry unwashed seed at the rate of 130 pounds of wet seed an hour, or approximately 1,000 pounds a day. Washed seed, however, can be dried more quickly. The drier could easily be built by a carpenter in a few days, and the cost for material,

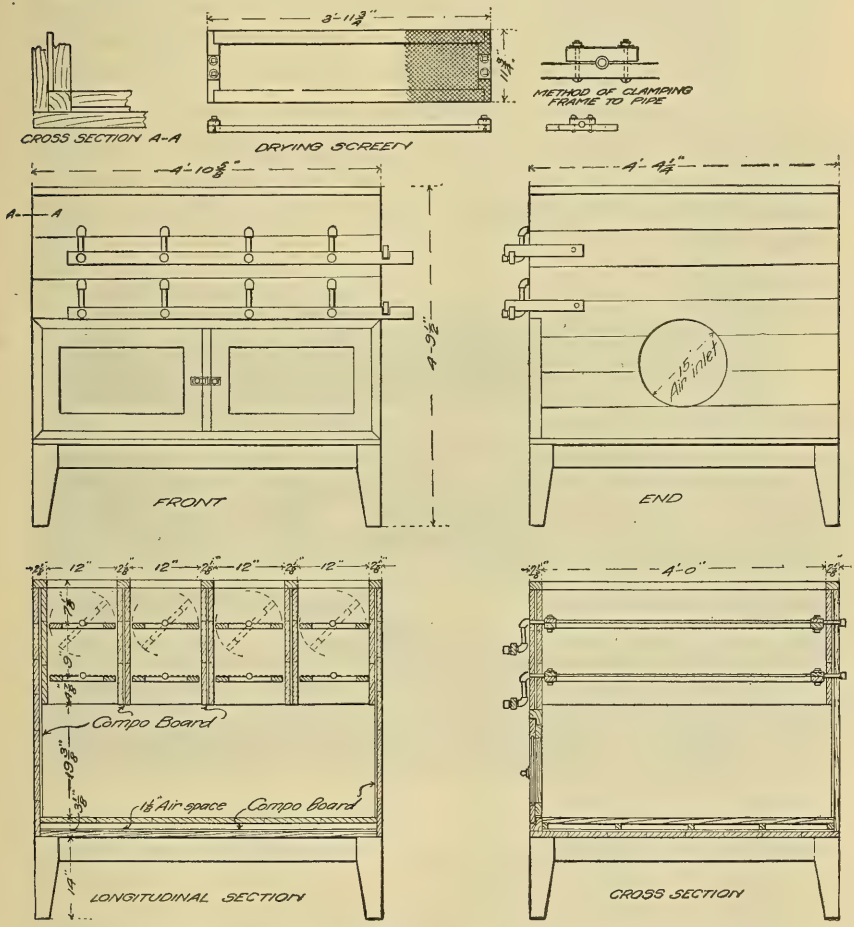

Fig. 7.—A trayless drier.

using ordinary building material, would be approximately $40. One hundred dollars would doubtless cover the entire cost for labor and material. The cost of a fan would be approximately $50, while a heater and piping would add about $100 more.

Considerable attention was directed to the performance of the rotary type of direct-heat drier. It might be thought that the preliminary mechanical reduction of moisture from 65 to 50 per cent is

so slight that the extra handling would be unprofitable. However, such treatment seems to be necessary in order to make the subsequent drying by the rotary drier successful. If the seed contains more than 52 to 55 per cent of moisture, it has a tendency to pack and stick to the walls of the drier instead of drying and discharging freely. In the experiments conducted none of the expeller or centrifuged seed packed in the drier, but in every case the untreated seed did pack.

An experimental direct-heat drier (fig. 8) was installed for the work, the heat being supplied by gas. The seed-drying chamber of this machine was 5 feet long by 1 foot in diameter and rotated at

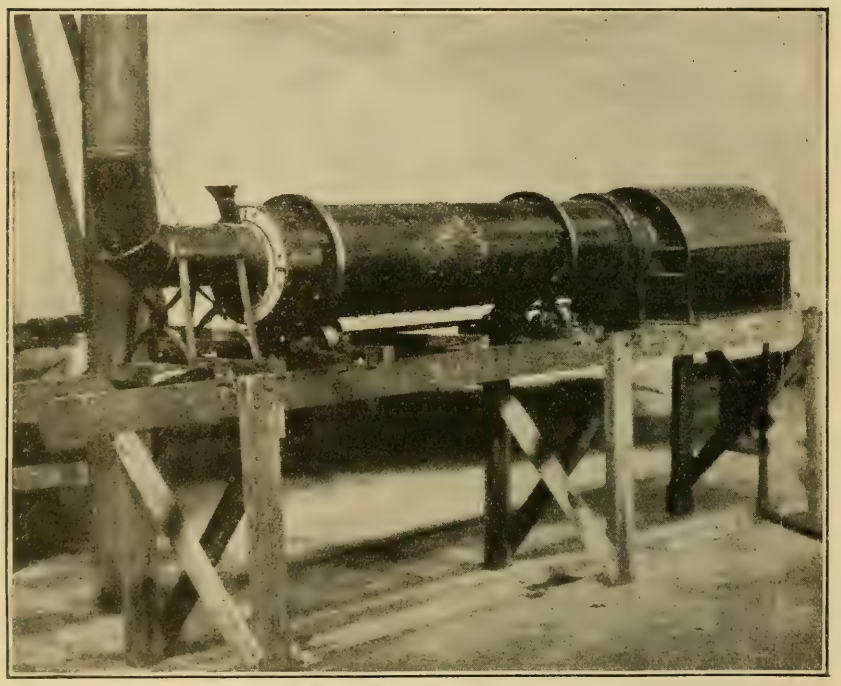

FIG. 8.—An experimental direct-heat drier.

the rate of 16 revolutions per minute. About six or seven minutes were required for the seed to pass through the machine. Inasmuch as this period was too short for complete drying, several passages through the drier were necessary. Trials on a semicommercial scale demonstrated that such a machine is readily adapted to the drying of such material as washed tomato seed, since it is easily controlled, is continuous in operation, and carries a minimum labor charge because it requires but little attention.

In order to produce seed of proper dryness it was necessary to pass it through the machine three times. The moisture content, which at the beginning was 52.4 per cent, at the end of each passage

was reduced, respectively, to 35.6, 21.9, and 9.6 per cent. In a fifth passage through the drier the moisture was reduced to 3.1 per cent.

It is, of course, apparent that a large commercial drier of this type (fig. 9) would be materially longer than the experimental drier, and probably one passage of the seed through the machine would reduce the moisture to about 10 per cent, which would be sufficient for subsequent oil extraction.

It is thus evident that one workman could handle the whole operation of seed treatment from the seed-washing cyclone through the moisture expeller and drier to the storage-bin conveyors.

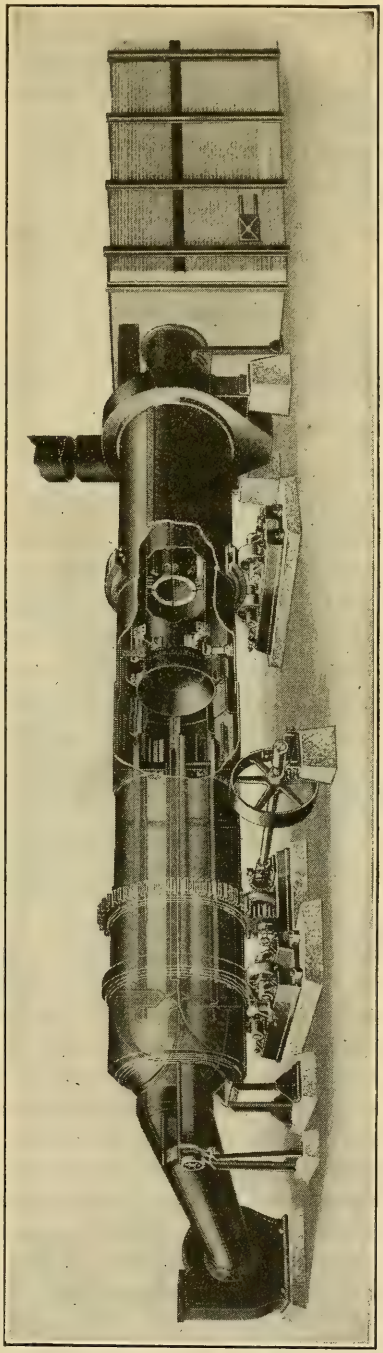

FIG. 9.—A commercial direct-heat drier.

THE USE OF EXHAUST STEAM COMPARED WITH LIVE STEAM.[5]

The advisability of using exhaust steam for heating the air with which to dry the seed depends (1) upon the other uses to which the available steam might be put and (2) upon the cost of producing live steam. Data from seed-drying plants show that with air heated to about 185° F. delivered at a rate of 2,000 cubic feet per minute the seed from a 5,000-basket pulping station may be dried in an eight-hour day. The quantity of steam necessary for this heating is 250 pounds an hour.

[5] Contributed by J. C. Smallwood, Johns Hopkins University.

With steam at 50 cents a thousand pounds, which probably is as low as could be obtained at the present prices for fuel and labor, the total cost for heating the air during a season of, say, 50 eight-hour days would be $50.

Table IV shows the size and character of the equipment required for exhaust and live steam, respectively.

TABLE IV.—*Comparison of the size and character of the respective equipments required for exhaust and live steam in drying tomato seed.*

Equipment.	Exhaust steam.	Live steam.
Size of pipe line	1½ inches	½ inch.
Length of pipe line	Probably greater	
Accessories	Oil separator	Trap.
Heating surface of radiator	Same, if	Reduced pressure with reducing valve is used.
	Greater, if	Full steam pressure is used.

The cost of these installations will vary in every plant. It should be noted, however, that if there is a small engine near the drier, all or part of its exhaust steam may be piped to the radiator and allowed to flow through it continuously without the use of a trap.

Allowing 6 per cent for interest on the investment and 12 per cent for depreciation, etc., an increased expenditure of as much as $275 for equipment for the use of exhaust steam over that for live steam would be justified. If the cost of live steam is more than 50 cents a thousand or the season longer than 50 days, even a greater expenditure would be justified, with a possible increase in saving.

EXTRACTING THE OIL FROM TOMATO SEED.

Two methods are used for extracting oil from oleaginous seeds—pressure and solvent extraction.

The apparatus best suited for extracting oil by pressure is the expeller type of press (fig. 10), which is admirably adapted for pressing seeds that contain from 18 to 20 per cent of oil. A description of this press is unnecessary, since by its wide use in the oil-seed trade it has already become more or less familiar.

To test the effect of the expeller in the extraction of tomato-seed oil, seed under varying conditions was passed through the machine, as follows: One lot of seed was washed, dried, and handled in the usual manner; another lot was allowed to ferment in its own moisture for about five days, since it was recognized that much of the seed which would be assembled at the utilization centers would perhaps be in varying stages of spoilage. One lot of seed which had heated in storage because of previous insufficient drying was redried and passed through the expeller. Another lot consisting of uncleaned fresh seed with quite appreciable quantities of small pieces of skin attached was dried and pressed. The results of the expeller tests of these various lots of seed are shown in Table V.

TABLE V.—*Expeller tests of various lots of tomato seed dried in rotary and tray driers.*

Kind of seed.	Weight of product (pounds).			Net results (per cent).	
	Seed pressed.	Oil obtained.	Foots.	Oil.	Oil and foots.
Rotary drier:					
Normal	67.5	10.25	Trace.	15.1	15.1
Fermented	50	8	1.75	16	19.5
Heated	73.25	10.25	Trace.	14	14
Uncleaned	20	2.75	Trace.	.....	13.7
Tray drier:					
Normal	63.75	12.0	Little.	.....	18.8
Fermented	81.25	15	1.75	18.4	20.6

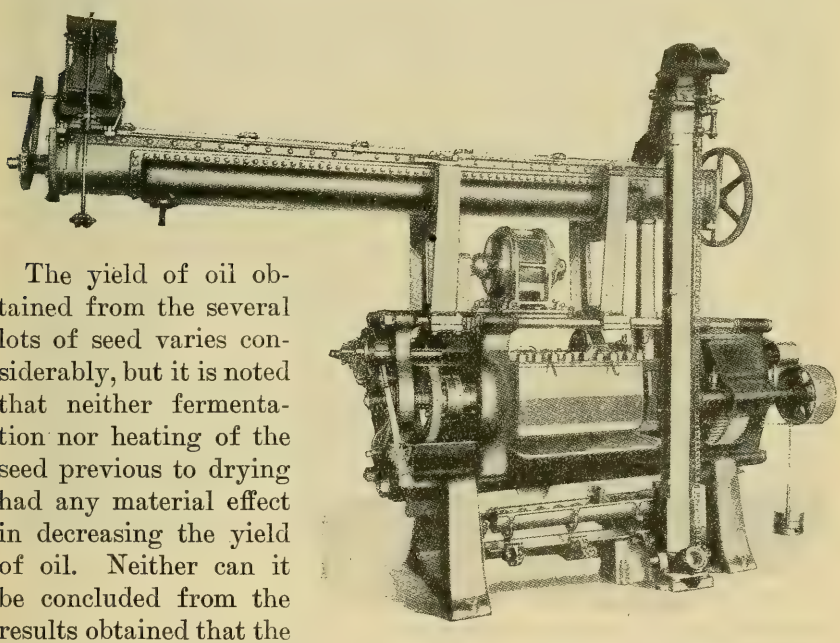

FIG. 10.—A commercial oil expeller.

The yield of oil obtained from the several lots of seed varies considerably, but it is noted that neither fermentation nor heating of the seed previous to drying had any material effect in decreasing the yield of oil. Neither can it be concluded from the results obtained that the seed dried in the tray drier produced a higher yield of oil than that dried in the rotary drier. The apparently higher yields are explained by the fact that before the tray-dried seed was run through, the expeller had been operated for several hours, thus causing a higher temperature, due to the heating of the barrel. Furthermore, the adjustments necessary for the efficient operation of the expeller with this particular material had been perfected when the tray-dried seeds were passed through. A yield of about 17 per cent of oil can therefore be expected from tomato seed by means of a perfectly adjusted expeller operating at its greatest efficiency.

In this connection, it may be stated that the oils obtained from the several lots of seed varied somewhat in color, from a pale golden yellow to a deep reddish brown. The lightest colored oil was obtained from heated seed dried in a rotary drier. This lot, however, gave the lowest yield of oil. The uncleaned seed yielded the darkest colored oil. Not enough difference was noted in either the yield or character of the oils to warrant the assumption that the heating or fermenting of seed, such as would probably take place in transit from the pulping station to the central reduction plant, would have an especially deleterious effect on the oil.

Solvent extraction of oil-bearing seed is at present receiving the attention of oil technologists, principally because of the higher yield of oil obtainable. It consists essentially of percolating the material with a suitable solvent which dissolves the oil and is subsequently recovered from the oil solution and from the residue by distillation. Benzol is perhaps the most satisfactory solvent used for this purpose at the present time. However, other solvents, such as gasoline, petroleum ether, and carbon tetrachlorid, are of value.

In the experiment made in the laboratory the seed was ground and extracted with benzol by maceration. The solution of the oil in benzol was placed on a steam bath and freed from the solvent by vacuum distillation. The yield of oil by this process was 20.7 per cent.

A modified method of solvent extraction is embodied in the so-called Cobwell process (fig. 11), which is being applied in garbage utilization and for other similar purposes. This process is applicable to oil-bearing materials with a high content of water. The process operates on the principle that when a wet mass is mixed with a volatile solvent and distilled the vapor tension of both water and solvent is lowered, whereby the mixture of the two vapors passes over into the condensing system. By renewing the solvent from time to time as the liquid mixture boils off it is apparent that the later distillates will become richer in solvent and weaker in water until practically all the water has been eliminated. Distillation is then stopped and the mass percolated with the solvent, whereby the oil is extracted and drained off with the solvent. This solution is pumped into a still and heated, which causes the solvent to vaporize and condense in an appropriate equipment, while the oil remains behind in the still.

It is apparent that this process obviates the necessity for seed separation, moisture reduction, and drying and at the same time yields the oil in one treatment of the raw waste.

The disadvantage of the process and of the one previously described is that both yield solvent oils, which bring a lower market price than pressed oils.

REFINING AND DEODORIZING THE OIL.

The tomato-seed oil obtained by the expeller process was deep brownish in color and possessed a strong odor. It was refined, bleached, and deodorized on a semicommercial scale by the usual method of procedure. After determination of the free acids in the oil a slight excess of caustic-soda solution (sodium hydroxid), about 16° Baumé (1.124 sp. gr.), was added gradually to the warm oil, with constant stirring. After thorough agitation the temperature was slowly raised to about 150° F. Under this alkali treatment an

FIG. 11.—A commercial installation of the Cobwell process of solvent extraction.

excellent break was obtained. The precipitate was allowed to settle and the clear supernatant oil was drawn off. The oil was pale brownish red in color.

The optimum bleaching temperature was found to be 110° C., using 6 per cent XL fuller's earth and 3 per cent filtchar. The filtration was carried out in an ordinary laboratory filter press, using about 5 pounds pressure. The bleached oil had the appearance of virgin peanut oil. Deodorization was accomplished by passing a current of steam through the oil at an atmospheric pressure at 105° C. for 2 hours. The resulting oil was excellent in quality. Deodorization in a vacuum in modern improved apparatus would doubtless pro-

duce an oil comparable in quality to the common edible oils of commerce.

The solvent-extracted oil, which had an acidity of 1.55 per cent, was refined by using 16° Baumé sodium-hydroxid solution held at 28° C. for about 25 minutes, then heated slowly to 45° C. during a 15-minute interval. After standing several hours the clear oil was decanted, slowly heated to 120° C., and treated with 6 per cent of a good grade of fuller's earth which had been previously heated. Deodorization of this oil was carried out at 200° C. under a vacuum of 27 to 28 inches for two hours. The colorimetric readings of the refined and bleached oil made with a Lovibond tintometer in a half-inch cell were 17.0 yellow and 1.6 red. The finished oil appeared to be equal to that obtained by pressure and gave readings in the standard cell of 18.5 yellow and 2.4 red. It would seem, therefore, that a very satisfactory grade of tomato-seed oil can be produced by solvent extraction, since the oil yields to refining, bleaching, and deodorizing equally as well as the pressed oil.

OIL CAKE AND MEAL.

The value of the oil cake or meal as a stock food has been demonstrated in Italy, where the utilization of tomato waste is in practical operation. An analysis of tomato-seed meal shows the following composition: Moisture, 7.15 per cent; ash, 4.64 per cent; protein, 37 per cent; nitrogen-free extract, 29.1 per cent; and fiber, 22.1 per cent. This analysis compares favorably with several of the better known meals of commerce, as shown in Table VI. The meal or cake possesses value not only as a cattle food, but also as a hog and chicken food. The slightly bitter taste which accompanies it can be effectively masked when used as a mixed stock food.

TABLE VI.—*Composition of various commercial stock feeds compared with that of tomato-seed meal.*

Feeding stuff.	Constituents (per cent).					
	Moisture.	Ash.	Protein.	Nitrogen-free extract.	Fiber.	Ether extract.
Tomato-seed meal	7.15	4.64	37.0	29.1	22.1	.....
Cotton-seed meal	7.8	6.6	39.8	27.4	10.1	8.3
Sunflower seed (prime)	10	4.2	34.8	21.8	10.9	18.3
Sesame oil cake	9.8	10.7	37.5	21.7	6.3	14
Palm-nut cake	10.4	4.3	16.8	35	24	9.5
Rape-seed cake	10	7.9	31.2	30	11.3	9.6
Linseed meal (new process)	9.6	5.6	36.9	36.3	8.7	2.9

COMMERCIAL PROCEDURE FOR UTILIZING TOMATO WASTE.

In any commercial utilization project the cost involved in handling and reducing the material largely determines its profitableness, and the quantity and condition of the waste handled are important considerations.

Since no one pulping plant is likely to produce enough seed to make it practicable to install the equipment necessary for crushing the seed for oil, the most logical procedure, it seems, would be to assemble the seed from the various pulping plants at some central point where the necessary machinery could be installed.

To get the seed to a central plant two courses are possible: (1) To separate the seed at the pulping stations and send it to the utilization center for drying, or (2) to separate and dry the seed at each of the pulping stations.

In the first case, where the wet seed is shipped directly to the central plant for drying and crushing, several points are to be considered. The seed as it comes from the machine contains from 65 to 70 per cent of moisture; hence, to assemble the wet seed at a central plant would involve a heavy freight charge for hauling the moisture.

The profits might be great enough to bear this expense if the place for assembling the seed was not so far away from the producing centers as to consume too much time in transit, on account of the rapidity of spoilage of the seed. Also, if shipped in less than carload lots, there would be an increased freight charge. Since a 5,000-basket plant produces only about three-fourths of a ton of wet seed a day, fully three weeks would elapse before a minimum carload shipment (15 tons) could be ready. It has been found that spoilage over a short period does not deleteriously affect the yield or quality of the oil, but a long period would doubtless result disastrously. Stations within a short hauling distance of the utilization center could, of course, ship the wet seed.

At smaller plants which produce less seed or which are situated at greater distances it would be necessary to dry the seed before shipment. Local conditions, therefore, would determine whether the product of a given plant should be dried or shipped wet.

Where the wet seed is shipped directly to the central plant to be cleaned and dried, there should be proper and sufficient equipment to handle the material readily as it arrives. It would be necessary to have a conveyor to unload it from the car directly to the storage bins. Thence it should go by means of chutes directly to the washing cyclones, which should be of sufficient number and capacity to handle as much seed as is produced by all the contributing pulping stations at their peak production, which comes during the last week of August and the first two weeks of September. In washing the seed it should be mixed with about 8 or 10 times its weight of hot water and pumped by centrifugal pumps directly into the washing cyclones, whence it could be delivered to a conveyor which would carry it to the hopper of the moisture expeller. It might even be possible to eliminate the cyclone washing of the seed by pumping it into a bin with ample drainage and thence delivering it directly to the moisture expellers.

From these machines the seed would be conveyed directly to the rotary or the tray driers and thence into the storage house. The whole operation would thus be continuous, and labor would be kept down to a minimum.

It is understood, of course, that this portion of the plant would operate only during the pulping season. If the oil were to be extracted at this central point, oil expellers could be installed and the seeds crushed during the winter months.

To handle this material it would be necessary for some operating company to install a plant at some central point, as suggested above. Preferably all the seed-separating machines installed at the various pulping stations should belong to the operating company and be assigned to the local concern, the cost being charged against the investment. The matter of credits to the pulping plants for seed contributed could be established by buying on a tonnage basis figured as wet or dry seed, as the case warranted.

As an alternative there could be a cooperative holding company consisting of all the seed producers, who would handle the seed to the drying stage and then either install an oil mill for pressing it or contract with a regularly established oil mill to make the crush. In any event the profits would be divided among the stockholders (cooperating firms). This would insure the necessary tonnage of seed supply and at the same time involve the use of but little machinery outside of that regularly used in a pulping station. It is recognized that the individual profits would be small, but withal far more than are now realized, for in most cases the seed is now an actual expense. It is even suggested that there be a national association of the canners to operate the plan, thus profitably utilizing another waste material, as is already being accomplished in many other lines of canning and packing.

The second plan involves no central utilization plant as such. Under this plan seed-separating cyclones would be installed at every pulping station, together with a drier, preferably the tray drier previously described, on account of its more adaptable size. Since it costs but little more to operate a large than a small drier, it would probably be best to install one large enough to handle the entire output of a given station within two or three days. By this plan the seed would be allowed to accumulate for that length of time and would be dried at once, thus reducing the cost of labor to three days a week. The individual plant would be under no charge for cyclone or drier, as these would be installed by the operating company and the initial cost of installation would be borne by the capitalization. If made in lots of 25 or 50 of standard pattern, the cost of the driers would be reduced to a minimum. The dried seed could then be shipped when convenient to some central regularly

operating oil mill, which would crush it either on a pro rata basis or on a flat contract, depending on the arrangements effected.

If the Cobwell system of extraction be adopted, the wet seed would have to be accumulated at a central point, since the drying and extracting are done at the same time. The operation of such a plant would necessarily cease with the packing season unless other material could be obtained for oil extraction. It has been suggested that butcher's trimmings, which are produced in the largest quantities mostly during the winter months, would supply the plant with material between seasons.

COST OF HANDLING THE WASTE.

In determining the approximate cost of a utilization project of this character it is necessary to consider the expense involved in all the operations from the assembling of the seed to the manufacture of the oil and press cake. This latter would, of course, involve the cost of the plant and equipment.

SEPARATING THE SEED.

As previously stated, the cost of seed separation is negligible, since in ordinary practice one man can operate three or four, or sometimes even six or eight, cyclone machines, depending on the character of the layout. Since a 5,000-basket plant usually operates two pulping cyclones, a single cyclone for separating the seed can readily be operated with no extra labor charge.

ASSEMBLING THE SEED.

If the pulping station is located in a city or in any place from which seed or other waste must be hauled away, the cost of assembling such seed for shipment would place no financial burden on the recovery operations, because in either event a hauling charge would be necessary. If, on the other hand, the station is located in the country, where no hauling charge is involved, there would be the necessary cost of loading the seed on a car for shipment to the utilization center.

To ascertain the most satisfactory place for a central plant, data on freight rates were collected, showing the cost of delivery of seed to each of the following places: Philadelphia, Pa.; Westfield, N. Y.; Chicago, Ill.; and Indianapolis, Ind. If all the seed were shipped to one central point, the most likely center would be Westfield, N. Y., for the East, and Indianapolis, Ind., for the Middle West; but if the operation were to be conducted in a more or less restricted area, then the cheapest freight rates would, of course, group about the nearest center.

At present there is no oil mill located at Westfield, N. Y., but this point is included, together with Chicago, Indianapolis, and Philadelphia, in the estimates on freight charges.

The cost of assembling the seed at the various suggested utilization centers, together with the approximate quantity of seed produced, both wet and dry, in the several largest tomato-pulping States is given in Table VII. The figures for shipping wet seed are based on the rates charged for dry bagged seed. There is no classification for wet seed shipped in bulk, so it is to be assumed that such bulk rate would be no higher than the rates for shipment of dry seed in bags; hence, the freight cost of wet seeds as given is considered to be conservative.

TABLE VII.—*Cost of assembling wet and dry tomato seed at several possible utilization centers, together with the quantities of seed produced in the various States.*

Product and State.	Utilization centers.				Quantity of seed (tons).
	Chicago, Ill.	Indianapolis, Ind.	Philadelphia, Pa.	Westfield, N. Y.	
Wet seed:					
Delaware	$1,440	$1,300	$630	$1,050	96
Illinois	165	2,060	4,030	2,805	184
Indiana	3,400	2,055	6,860	4,182	616
Kentucky	135	90	229	170	15
Maryland	3,500	3,240	1,500	2,340	385
New Jersey	4,120	3,930	970	2,480	267
New York	1,980	2,000	850	900	147
Ohio	990	980	1,356	1,005	120
Pennsylvania	1,560	1,410	837	1,120	92
Unreported [1]	12,160	9,870	6,065	8,220	1,127
	29,450	26,935	23,318	24,272	3,049
Dry seed:					
Delaware	480	430	210	350	31
Illinois	55	480	935	660	61
Indiana	970	603	2,000	1,240	205
Kentucky	45	30	75	60	5
Maryland	1,170	1,080	500	780	130
New Jersey	1,070	995	305	665	88
New York	575	540	235	255	49
Ohio	265	260	365	280	40
Pennsylvania	415	385	200	320	30
Unreported [1]	4,050	3,290	1,860	2,740	375
	9,095	8,092	6,685	7,350	1,014

Unreported firms are those who failed to respond to the request to furnish statistics of consumption. The estimates for these are based on general information.

The total cost of shipping wet seed to the several drying centers would average $26,000 for 3,000 tons (about 1,000 tons of dry seed). To ship the dry seed would cost about $7,800.

DRYING THE SEED.

Since it is necessary that the seed be dried either at each pulping station or at a utilization center, the cost of drying will have to be figured accordingly. For convenience, Table VIII is presented to show the number and size of the several pulping stations. In order to determine more conveniently the cost of drying the seed at each of the pulping stations, they have been listed according to their capacity.

TABLE VIII.—*Number and size of tomato-pulping plants in operation.*

Size of plant.	Number of plants.	Size of plant.	Number of plants.
Under 1,000 tons	20	6,000 to 8,000 tons	3
1,000 to 2,500 tons	24	8,000 to 10,000 tons	1
2,500 to 4,000 tons	7	Over 10,000 tons (17 units)	2
4,000 to 6,000 tons	5		

If the seed is to be dried at each of the pulping plants, a small tray drier (previously described) would be the most economical to install for the purpose. If a 4,000-ton plant, pulping 5,000 baskets of tomatoes a day, requires one drying unit (all the plants under 1,000 tons being eliminated from consideration), there would be 31 in this class (for fractions of a unit must be considered as a whole unit). The eight plants of the succeeding two classes would require 16 more units, while the plants in the last two classes would require proportionately more units, or about 20. On this basis the total number of drying units required for the several plants would actually be 67, but 70 is adopted to allow for possible fractional capacities.

EQUIPMENT FOR DRYING.

The cost of the necessary equipment, including the cyclone heating and drying units, together with the operating cost for drying the seed at the pulping plants, is approximately as follows:

	Estimated cost.	
Equipment:		
Seed-separating cyclone	$200	
Pump	50	
Piping	50	
Drier	100	
Fan	50	
Heater	100	
Housing	50	
Steam piping	100	
Total cost of equipment for one drying unit	700	
Total cost of equipment for drying at 70 pulping stations		$49,000

The cost of operation has been calculated as follows:

Operating costs:	Estimate.	
Depreciation, at 10 per cent	$4,900	
Labor (including shipping labor), 1 man at 40 cents an hour for 10 hours per unit (4×70×60)	16,800	
Power	4,200	
		25,900
Total cost		74,900

If the wet seed is to be dried at one central drying plant it would still be necessary to install at each pulping plant seed-separating cyclones. This wet seed after arriving at the drying center would be subjected to the operation of washing, expelling the moisture, and drying, the latter operation being conducted in rotary driers. Such a plant would operate 24 hours a day, handling the peak production of 50 tons of wet seed a day over a season of about 60 days.

The following equipment would be necessary for a plant of this kind:

		Estimated cost.
Conveyor to holding tank		$60,000
Tank and stirrer		
Piping to cyclones		
10 cyclones or tank and conveyor		
Conveyor to expellers		
4 moisture expellers		
Conveyor to driers		
5 driers		
Conveyor to bagging machine		
Bagging machine		
Piping, shafting, etc		
Boiler and engine		
Freight and incidentals		
Pump, traps, valves, etc		
Drilling well, etc		
70 cyclones at pulping stations, at $200 each	$14,000	
70 pumps, at $50 each	3,500	
Piping, freight, etc	10,000	
Incidentals	5,000	
		32,500
Total cost of equipment for drying the seed at a central drying plant		92,500

The cost of operation is estimated as follows:

Labor (loading wet seed into cars)	$1,600
Depreciation of plant, at 10 per cent	9,250
Labor, per day, $159.20 (approximate cost), for a season of 60 days	9,552
Management (manager at $3,500, clerk at $1,200), three months	1,175
Power (500 tons of coal at $8 per ton)	4,000
Total	25,500

A summary of the costs of assembling and drying the seed at a central drying plant and at the several pulping plants is given in Table IX.

After separating, assembling, and drying, the seed is ready for the extraction of the oil. The cost of this procedure will depend on the method of extraction employed, whether it be the expeller or the solvent method.

TABLE IX.—*Operating costs of assembling and drying seed at a utilization center and at the pulping plants.*

Cost.	Drying center.	Pulping plant.
Depreciation	$9,250	$4,900
Labor (including shipping)	11,152	16,800
Power	4,000	4,200
Management	1,175	1,175
Assembling (average)	25,994	7,806
Total	51,571	34,881

EQUIPMENT FOR EXPELLING THE OIL.

The same building which housed the cleaning and drying machinery during the pulping season could be equipped with oil expellers for crushing the seed during the winter months. For such a plant the following equipment would be necessary:

5 expellers, 1 sump tank, 2 conveyors, 1 filter press, 2 grinding mills, 3 pumps, 2 tanks, piping, and miscellaneous. The estimated cost is	$30,000

The operating cost for expelling the oil from 1,000 tons of dry seed, with the depreciation cost of the machinery and the labor and power charges at current rates, is as follows:

Depreciation of the plant, at 10 per cent	$3,000
Labor (1 mechanic, 1 engineer, 1 fireman, 2 laborers, and 1 foreman)	6,100
Power (600 tons of coal at $8 per ton)	4,800
Management (manager at $3,500, clerk at $1,200) for 9 months	3,525
Total	17,425

The installation of a solvent-extraction plant would probably cost about the same as an expeller plant, namely, $30,000.

The operating cost of extracting 1,000 tons of dry seeds is estimated to be as follows:

Depreciation of the plant, at 10 per cent	3,000
Labor	6,100
Power (500 tons of coal at $8 per ton)	4,000
Management	3,525
Total	16,625

The above operating costs for both expeller and solvent extraction are perhaps rather high, since the figures are based on the output of tomato seed only and represent but a comparatively short period of time, the equipment being idle for a large portion of the year unless something else, such as grape seed, pumpkin seed, or some other oleaginous material, can be worked during this idle period. In the event that other materials were worked, the overhead cost would be reduced accordingly and the profits augmented proportionately.

Since it is shown (Table IX) that the most economical operation is involved in drying the material at the respective pulping plants, the total handling cost of this utilization project would be the sum of the cost of preparing the seed and the manufacture of the oil by either the expeller or the solvent-extraction method, which is shown in Table X.

TABLE X.—*Comparison of the cost of tomato-seed utilization by either the expeller or the solvent-extraction method.*

Operation.	Expelling.	Solvent extraction.
Preparation of seed	$34,881	$34,881
Recovery of oil	17,525	16,625
Total handling cost	52,406	51,506

POSSIBLE RETURNS AND NET PROFITS FROM OIL, CAKE, AND MEAL.

In estimating the possible returns from the oil, cake, and meal obtained from the seed, a price of 16 cents a pound for expeller oil and 14.5 cents a pound for extracted oil was used as the basis of calculation. The value of the oil cake was estimated on the basis of $40 a ton, or 2 cents a pound, and the solvent-extracted meal at $30 a ton, or 1.5 cents a pound.

The gross and net returns from oil, oil cake, and meal from 1,000 tons of tomato seeds manufactured by the two processes described and yielding 17 and 20 per cent of oil by expression and solvent extraction, respectively, are shown in Table XI.

TABLE XI.—*Estimated gross and net returns from tomato-seed oil, cake, and meal obtained by either the expeller or the solvent-extraction process.*

Products.	Quantity (pounds).	Price per pound (cents).	Value.	
			Expeller.	Solvent extraction.
Oil	340,000	16	$54,400	
Do	400,000	14½		$58,000
Cake	1,660,000	2	33,200	
Meal	1,600,000	1¾		28,000
Total gross returns			87,600	86,000
Cost of oil recovery			52,406	51,506
Net returns			35,194	34,494

It is estimated that an oil-extraction plant will handle the entire tomato-seed waste in two months, which, added to the three months of the operating season during the summer when the seeds are collected and prepared, represents five months' operation throughout the year. The above profits, therefore, which represent an operating season of five months, could be increased by extending the opera-

tion to other materials, thereby decreasing the overhead charges and adding to the profits already accrued. A plant equipped and operated by an association of canners or packers would have sufficient waste materials of various kinds from the different canning operations to enable it to run throughout the year, thereby reducing the overhead charges and increasing the profits very materially.

SUMMARY.

It has been shown that the waste from the pulping of tomatoes accumulates in vast quantities at the various pulping stations in the eastern and middle-western tomato belts. This material is at present entirely wasted, and in many cases its disposal entails considerable expense to the producers.

Investigation of the practicability of utilizing this waste shows that by the application of proper methods the seeds may be separated from the waste and made to yield oil and press cake or meal of considerable commercial value, the former as a table or culinary oil and the latter as stock feed.

From the estimates made on the cost of separating, assembling, drying, and crushing the seed, together with the cost of the necessary equipment, considerable profit is indicated from an undertaking based on the utilization of this waste.

The most feasible and economical method of procedure apparently lies in separating and drying the seed at the various pulping stations and shipping it to a utilization center, where the commercial products can be manufactured.

A cooperative plan of manufacture by an association of canners and packers of which practically all tomato-pulping concerns are members would perhaps be the most feasible method for the practical utilization of the waste, not only from tomatoes but from other products as well.

With the growth and expansion of the industry from year to year, the returns from an undertaking of this character would be augmented in proportion to its growth, since the quantity of waste is dependent upon the annual output of tomato products.

The utilization of an agricultural waste of this character for the production of commodities of much commercial value is suggested as a conservation measure worthy of careful consideration.

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SUBSTITUTES FOR SUCROSE IN CURING MEATS.

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QUANTITY OF SUGAR USED IN CURING MEATS.

Sugar is used extensively in the curing of meats in this country. In 1917, 15,924,009 pounds of sugar as such and 1,712,008 pounds in the form of sirup, or a total of 17,636,017 pounds, was used in curing meats in pickle in Government-inspected establishments. In addition, a considerable quantity of sugar was used in curing meats in the dry way, so that the total quantity of sugar used in curing meats probably amounted to about 20,000,000 pounds. This estimate does not include the amount of sugar used in curing meats on the farm, for which there are no data available.

At the time the sugar shortage developed in this country during the war, an investigation was started to ascertain how the greatest economy in the use of sugar in curing meats could be effected. Several methods appeared feasible but the use of certain sugar substitutes appeared to be the most practicable one. A series of carefully controlled experiments in the curing of several classes of meats with a number of sugar substitutes and with cane sugar was carried on in three large and one small meat-packing establishment. This investigation was completed a short time before the signing of the armistice, and while the war-time need for the information has passed, yet it is believed that the results of these experiments may be of present value.

FUNCTION OF SUGAR IN CURING MEAT.

Sugar is used in curing meat chiefly on account of its effect upon the quality of the product. "Sugar-cured" hams and bacon are supposed to be of superior quality. A very large proportion of the fancy hams and bacon on the American market has been cured with the use of sugar or sirup.

Sugar is not used in curing meat on account of its preservative action; in fact, it is probable that the quantity of sugar ordinarily used exerts but very little, if any, preservative action. Meat can be cured in entire safety without the use of any sugar, and large quantities are so cured.

SUBSTITUTES FOR SUGAR.

The sugar generally used in curing meats is sucrose in the form of granulated, clarified, or plantation-raw sugar. In addition, a considerable quantity of second-grade refiners' sirup is also used. This grade of refiners' sirup is not suited to replace granulated sugar in the household.

The essential requirements for sugar substitutes used in curing meats are: (1) The cured meat should be of as high quality as that cured with sucrose; (2) there should be practically no spoilage of meat during the curing process; (3) the substitute should be available in sufficient quantities and at a price comparable with that of sucrose. The following products were investigated as to their suitability for the purpose.

REFINERS' SIRUP.

Refiners' sirup, second grade, is a dark-colored, strong-flavored product resulting from the refining of cane sugar. It is variable in composition and quality and is usually purchased on specifications as to sugar and ash content. The total domestic production of first- and second-grade refiners' sirup in 1918 is estimated by one of the large sugar-refining companies to have been 345,000,000 pounds, which is equivalent to approximately 210,000,000 pounds of sugar. Data on the production of second-grade sirup could not be obtained. It appears that the total supply of refiners' sirup is about ten times greater than the amount required to meet the sugar needs of the meat-packing industry. First-grade refiners' sirup is much higher in price than the second-grade product, and for that reason is ordinarily not used in curing meats, and if the production of second-grade sirup is estimated as half the total production, then the lower-grade sirup would supply approximately five times as much sugar as is needed in curing meats. However, the total supply of this grade of sirup is not available for the purpose.

There is considerable difference of opinion among meat-packing establishments as to the value of refiners' sirup for use in curing meats. A considerable number of establishments use sirup exclusively in curing pork products in pickle, with very satisfactory results; on the other hand, a large proportion of the meat-packing establishments do not use sirup at all. According to the data previously cited regarding the use of sugar and sirup in curing meats in pickle during 1917, it appears that approximately 10 parts of sugar as such were used as compared with 1 part of sugar in the form of sirup.

CORN SUGARS.

There are at least three grades of corn sugar, besides glucose sirup, as follows:

1. Dextrose is a white powder resembling confectioners' sugar in appearance. It is mildly sweet and dissolves readily in cold water. It is nearly pure dextrose and contains only a small percentage of moisture.

2. Cerelose is the trade name for a second-grade corn sugar. It is sold in the form of very small, light-brown globules of a mildly sweet flavor. It dissolves fairly readily in cold water. It is supposed to contain about 86 per cent dextrose, 10 per cent moisture, and 0.6 per cent ash. This product is used extensively as a substitute for sugar. At the time of the acute sugar shortage during the war, the supply of this product was not nearly equal to the demand.

3. Seventy per cent corn sugar is a crude product marketed in the form of brown lumps of various sizes. It dissolves slowly in cold water and fairly readily in hot water, yielding a brown-colored, mildly sweet sirup. The manufacturer states that this product contains approximately 70 per cent dextrose, 20 per cent moisture, 0.6 per cent ash, and the remainder dextrin, etc. This product is ordinarily available in large quantities.

Glucose sirup was not considered on account of its relatively high dextrin and low sugar content, and because it was a much more expensive source of dextrose than the above-named corn sugars.

The following table shows the composition of the corn sugars and the sirups used in the experiments:

TABLE 1.—*Composition of corn sugars and refiners' sirup.*

Product.	Moisture.	Ash.	Sucrose.	Reducing sugar.	Dextrose.	Not determined.
Corn sugars:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dextrose	2.14	0.17	.....	.....	96.65	1.04
Cerelose	9.30	.65	.....	.....	84.73	5.32
70 per cent corn sugar	11.56	.65	.....	.....	77.75	10.04
Refiners' sirup:						
(a)	20.44	3.12	40.29	24.25	.....	11.90
(b)	20.12	4.42	40.95	22.46	.....	12.05
(c)	22.60	5.10	34.49	26.04	.....	11.77

EXPERIMENTAL WORK.

GENERAL PLAN.

Four series of experiments were carried out, one each with hams, sweet-pickle bacon, dry-cure bacon, and beef hams. These experiments were carried on in one small but modern meat-packing establishment and in three large establishments, which will be designated as X, A, B, and C, respectively. The general plan of the experiments was the same for each establishment. At each plant the work was conducted as nearly as possible in the same manner as was regularly followed in curing the several kinds of meat under investigation. In each experiment one package of meat was cured according to the regular practice in the establishment, while to each of the other packages an equivalent amount of each of the sugars under investigation was added in place of the sugar regularly used. In other respects all the packages at one establishment were handled in exactly the same manner.

EXPERIMENTS WITH PORK HAMS.

These experiments were carried on at each of the four establishments, but the one conducted at establishment X was of a preliminary nature and not so extensive as those carried on at the other plants.

PRELIMINARY EXPERIMENT AT ESTABLISHMENT X.

Three tierces of hams were cured at establishment X—one without sugar, one with granulated sugar, and one with cerelose. The chilled hams were packed in tierces, as follows: Tierce 1, a mixture of 8¼ pounds of salt and 7 ounces of sodium nitrate was sprinkled over the faces of the hams as packed; tierce 2, the same quantities of salt and sodium nitrate, and in addition 4½ pounds of granulated sugar were sprinkled over the faces of the hams in the same way; tierce 3 was packed in similar manner except that a like quantity of cerelose was substituted for the granulated sugar. The tierces were held 48 hours in a curing cellar at 35°–37° F. and were then headed, filled with 80° plain brine and held at the temperature stated until cured. The tierces were rolled on the fifth, fifteenth, and thirtieth days after packing. The cured hams were weighed, inspected for soundness, soaked 7½ hours in water to remove excess salt, and smoked 11½ hours. Two smoked hams from each tierce were selected for test purposes. A brief record of the experiment appears in Table 2.

TABLE 2.—*Record of preliminary ham-curing experiment, establishment X.*

Item.	Tierce 1, no sugar.	Tierce 2, granulated sugar.	Tierce 3, cerelose.
Number of hams	33	27	30
Curing period ... days	39	39	39
Weight of cured hams ... pounds	362	354	348
Condition of cured hans	Normal.	Normal.	Normal.

QUALITY OF THE CURED HAMS.

In this and subsequent tests the quality of the hams was judged from the appearance of the freshly cut surfaces of the hams and by the appearance and palatability of the fried product. Two hams from each lot were used for the purpose. The hams were tested by 11 persons, some of whom cooked and tested slices of ham in their homes while others attended a test conducted in the laboratory. The slices of ham were always fried in a clean pan and never in the drippings remaining after frying slices of another lot of hams. Those who tested the hams in their homes were instructed to observe similar precautions. A report of the test on the hams is presented in Table 3.

TABLE 3.—*Quality of hams (preliminary experiment at establishment X).*

Judge.	Tierce 1, no sugar.	Tierce 2, granulated sugar.	Tierce 3, cerelose.	Judge.	Tierce 1, no sugar.	Tierce 2, granulated sugar.	Tierce 3, cerelose.
	Points.	*Points.*	*Points.*		*Points.*	*Points.*	*Points.*
A	2	2	2	H	3	1	2
B	1	2	3	I	3	1	2
C	1	3	2	J	1	2½	2½
D	1	3	2	K	3	2	1
E	1	2	3				
F	1	2½	2½	Total	20	22	24
G	3	1	2				

Basis for scoring: First choice, 3 points; second choice, 2 points, third choice, 1 point. When no choice was indicated the samples were scored alike. The result of this test indicates that the hams cured with cerelose were considered to be slightly the best in quality, followed closely in turn by those cured with granulated sugar and with no sugar. There was really very little difference in the quality of the three lots of hams. It was noted, however, that the hams cured with sugar browned more readily on frying than those cured without sugar.

EXPERIMENTS AT ESTABLISHMENTS A, B, AND C.

PLAN OF WORK.

Six tierces of hams were cured at establishment A and five each at establishments B and C. The chilled hams were first pumped in the body and shank with 100° brine containing sodium nitrate and were then packed in tierces, which were finally filled with pickle. At each establishment the pickles for the several tierces were made up according to the same formula except as regards the kind of sugar used. It may be noted here that raw cane sugar was being used regularly at the time in curing this class of hams at establishments A and C and refiners' sirup at establishment B. At establishments A and B the tierces of hams were stored at a temperature approximately 36°–37° F., and at establishment C they were stored at a temperature of 40° F. The tierces were rolled on the fifth, fifteenth, and thirtieth days after packing.

At establishment A the cured hams were soaked 2¾ hours in water at 70° F. and were smoked 30 hours at a temperature approximating 130°–135° F. At establishment B the cured hams were soaked 2 hours and 20 minutes in water at 70° F. and were smoked 18 hours at 100° F. At establishment C the cured hams were soaked 3 hours in water 60° F. and were smoked 16 hours at 125° F.

Each lot of smoked hams was carefully inspected for soundness by a Government inspector. Two sound smoked hams were selected from each lot at each establishment for test purposes, except from one tierce at establishment B, which had been mislaid.

A record of the experiments is given in Table 4.

TABLE 4.—*Record of ham-curing experiments at establishments A, B, and C.*

Item.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
ESTABLISHMENT A.						
Number of hams	32	31	31	32	31	31
Curing period ... days	54	54	54	54	54	54
Weight of green hams ... pounds	300	300	300	300	300	300
Weight of cured hams ... do	327	328	328	324	320	329
Gain in weight ... do	27	28	28	24	20	29
Quantity of pickle ... gallons	13	14.5	16	16.75	17	15.5
Condition of smoked hams	Normal.	Normal.	1 light shank sour.	Normal.	Normal.	1 shank sour.
ESTABLISHMENT B.						
Number of hams	28	28	28	28	28	.....
Curing period ... days	45	45	45	45	45	.....
Weight of green hams ... pounds	290	290	290	290	290	.....
Weight of cured hams ... do	322	Tierce lost.	318	322	322	.....
Gain in weight ... do	32	.....	28	32	32	.....
Quantity of pickle ... gallons	18	18	16½	16¼	18¾	.....
Condition of smoked hams	Normal.	.....	Normal.	1 light shank sour.	Normal.	.....

TABLE 4.—*Record of ham-curing experiments, etc.*—Continued.

ESTABLISHMENT C.

Item.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 79 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
Number of hams	20	20	20	20	20	.....
Curing period ....days	55	55	55	55	55	.....
Weight of green hams ....pounds	280	280	280	280	280	.....
Weight of cured hams ....do	307	303	307	310	300	.....
Gain in weight ....do	27	23	27	30	20	.....
Quantity of pickle ....gallons	17	17	17	17	17	.....
Condition of smoked hams	Normal.	1 light aitchbone sour.	1 light shank sour.	Normal.	Normal.	.....

COMPOSITION OF PICKLE.

Table 5 indicates the composition of the new and old pickle from each tierce and of the pickle used in pumping the hams.

TABLE 5.—*Composition of new and old ham pickles at establishments A, B, and C.*

ESTABLISHMENT A.

Tierce No.	Age of pickle.	Kind of sugar.	Specific gravity at 20° C.	Salometer reading at 20° C.	Sodium chlorid.	Sodium nitrate.	Total sugar.
	Days.			*Degrees.*	*Per cent.*	*Per cent.*	*Per cent.*
1	New.	Granulated	1.144	72	16.15	0.57	3.92
1	54	....do	1.095	49	9.03	.35	2.68
2	New.	Dextrose	1.144	72	16.26	.51	3.74
2	54	....do	1.095	49	9.88	.42	2.48
3	New.	Cerelose	1.146	73	16.54	.53	3.62
3	54	....do	1.094	48	10.13	.33	2.46
4	New.	70 per cent corn sugar	1.147	74	15.61	.57	4.39
4	54	....do	1.095	49	9.97	.36	3.03
5	New.	Refiners' sirup	1.148	74	15.73	.57	4.16
5	54	....do	1.093	48	9.29	.44	2.87
6	New.	Raw sugar	1.144	72	16.15	.53	3.84
6	54	....do	1.092	47	9.62	.31	2.71
Pumping pickle.	New.	None	1.221	.....	23.10	6.49	.....

ESTABLISHMENT B.

1	New.	Granulated	1.138	70	16.07	0.29	2.80
1	45	....do	1.096	49	10.84	.25	2.19
2	New.	Dextrose	1.138	70	16.50	.29	2.55
3	New.	Cerelose	1.138	70	16.50	.29	2.53
3	45	....do	1.095	49	10.76	.22	1.87
4	New.	70 per cent corn sugar	1.138	70	16.18	.36	2.65
4	45	....do	1.095	49	10.58	.27	2.05
5	New.	Refiners' sirup	1.142	72	16.18	.31	2.78
5	45	....do	1.098	50	10.76	.24	2.08
Pumping pickle.	New.	None	1.210	.....	24.64	2.87	.....

ESTABLISHMENT C.

1	New.	Granulated	1.151	76	17.67	0.22	2.60
1	55	....do	1.104	53	11.70	.08	2.05
2	New.	Dextrose	1.150	76	17.27	.24	3.17
2	55	....do	1.100	51	11.19	.13	2.24
3	New.	Cerelose	1.150	76	17.17	.19	2.82
3	55	....do	1.103	53	11.56	.06	2.15
4	New.	70 per cent corn sugar	1.149	75	17.79	.23	3.16
4	55	....do	1.103	53	11.30	.19	1.68
5	New.	Refiners' sirup	1.152	76	17.24	.23	3.14
5	55	....do	1.097	49	10.31	.08	2.25
Pumping pickle.	New.	None	1.213	.....	25.32	2.19	.....

Table 6 shows the relative quantities of curing materials in the old pickle from each tierce, based upon 100 parts of each curing material in the new pickle.

TABLE 6.—*Relative composition of new and old ham pickles at establishments A, B, and C.*

Constituent.	Age of pickle.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
	Days.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
ESTABLISHMENT A.							
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00	100.00
Do	54	55.91	60.39	61.25	61.95	59.06	59.57
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00	100.00
Do	54	61.58	83.35	62.26	63.16	77.19	58.49
Total sugar	New.	100.00	100.00	100.00	100.00	100.00	100.00
Do	54	68.37	66.31	67.96	69.02	68.99	70.57
ESTABLISHMENT B.							
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	45	67.45	.....	65.21	65.39	66.44	.....
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	45	86.21	.....	75.86	75.00	79.35	.....
Total sugar	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	45	78.21	.....	73.91	77.36	74.82	.....
ESTABLISHMENT C.							
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	55	66.21	64.79	67.32	63.52	59.80	.....
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	55	36.36	54.17	31.58	82.61	34.78	.....
Total sugar	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	55	78.85	70.66	76.24	53.23	71.66	.....

These data indicate no great differences in the sugar content of the old pickle from the different tierces. There are considerable variations in the sodium-nitrate and sodium-chlorid contents of some of the pickles, but it is doubtful if they have any special significance. Attention is called to the fact that on the average the old pickle from the three establishments contains 63.38 parts sodium chlorid, 64.85 parts sodium nitrate, and 71.57 parts sugar, as compared with 100 parts present in the new pickle. The waste of curing materials occasioned by throwing away the old pickle from cured hams is apparent.

COMPOSITION OF THE HAMS.

Table 7 shows the composition of the hams. Analyses were made of the lean portion of a slice cut from the thickest part of each of two hams from each lot. While there is more or less variation in the composition of the several lots of hams, the data do not appear to have any special significance.

TABLE 7.—*Composition of hams at establishments A, B, and C.*

Constituent.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
ESTABLISHMENT A.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	49.28	54.42	54.97	50.10	54.38	55.68
Sodium chlorid	3.60	4.26	4.41	3.91	4.27	4.56
Sodium nitrate	.19	.25	.27	.23	.29	.25
Total sugar	.67	.36	.58	.59	.39	.36
ESTABLISHMENT B.						
Moisture	49.90	.....	56.27	52.95	53.11	.....
Sodium chlorid	4.52	.....	5.27	4.59	5.01	.....
Sodium nitrate	.11	.....	.10	.11	.09	.....
Total sugar	.36	.....	.50	.42	.53	.....
ESTABLISHMENT C.						
Moisture	45.52	45.17	51.33	53.30	42.20	.....
Sodium chlorid	4.96	4.33	5.80	5.15	4.40	.....
Sodium nitrate	.07	.06	.06	.07	.06	.....
Total sugar	.36	.50	.56	.42	.48	.....

QUALITY OF THE CURED HAMS.

The quality of the several lots of hams was judged in the same manner as described under establishment X, except that all the tests were made in the laboratory. Two hams from each tierce were tested for quality. In Table 8 is presented a report on the quality of the several lots of hams.

At establishment A the hams cured with refiners' sirup were considered to be of the poorest quality, and yet some widely distributed well-known brands of hams are cured with this grade of sirup. The opinion was very generally expressed by the judges that all the hams were of high grade and that there was really very little difference in the quality of the several lots.

A similar test of the quality of each of the several lots of hams in this experiment was carried on by the establishment in which the curing test was made, but with considerably varying results. However, by adding together the total number of points scored by each lot of hams in the two tests an average estimate of the relative quantity of the several lots is obtained, as follows: Tierce 1, granulated sugar, 76 points; tierce 6, raw sugar, 73 points; tierce 2, dextrose, 68 points; tierce 3, cerelose, 63 points; tierce, 5; refiners' sirup, 50 points; and tierce 4, 70 per cent corn sugar, 46 points.

At establishment B the basis for scoring was: First choice, 4 points; second choice, 3 points, etc. As before stated the hams in tierce 2 had been mislaid and were not scored. The results indicate that the

hams cured with 70 per cent corn sugar were of the highest quality, closely followed, in turn, by those cured with cerelose and granulated sugar, while those cured with refiners' sirup were considered to be of appreciably lower quality. Tierce 5, in which refiners' sirup was used as the source of sugar, was cured according to the regular practice at this establishment, except that the hams were cured in a tierce instead of in a large, open vat.

At establishment C the basis of scoring ranged from 5 to 1, as compared with 4 to 1 at establishment B, and 6 to 1 at establishment A. The data presented in Table 8 indicate that at establishment C there was comparatively little difference in the quality of the three lots of hams cured with granulated sugar, dextrose, and refiners' sirup. The hams cured with cerelose were of only slightly lower quality, and those cured with 70 per cent corn sugar were considered to be of poorer quality than the others, but all lots were of good quality.

TABLE 8.—*Quality of hams at establishments A, B, and C.*

Judge.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
ESTABLISHMENT A (OFFICIAL TEST).						
	Points.	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*
A	6	3	5	1	2	4
B	4	2	6	1	5	3
C	5	2	6	1	4	3
D	5	4	6	3	2	1
E	5	3	1	2	4	6
F	5	4	2	3	1	6
G	4	6	2	5	1	3
H	6	3	4	5	1	2
I	6	2	5	3	1	4
Total	46	29	37	24	21	32
ESTABLISHMENT A (PLANT TEST).						
M	5	6	4	1	2	3
N	1	2	3	6	4	5
O	2	3	6	1	4	5
P	5	2	3	4	1	6
Q	3	4	2	1	5	6
R	1	6	2	3	4	5
S	4	6	2	3	5	1
T	6	5	2	1	3	4
U	3	5	4	2	1	6
Total	30	39	28	22	29	41
ESTABLISHMENT B.						
A	4	.....	2	3	1	.....
B	2	.....	3	4	1	.....
C	2	.....	4	3	1	.....
D	1	.....	3	4	2	.....
E	4	.....	2	3	1	.....
F	4	.....	3	2	1	.....
G	1	.....	3	4	2	.....
H	2	.....	4	3	1	.....
Total	20	.....	24	26	10	.....

TABLE 8.—*Quality of hams at establishments A, B, and C*—Continued.

ESTABLISHMENT C.

Judge.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
	Points.	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*
A	5	4	3	1	2	.....
B	1	3	5	2	4	.....
C	1	3	2	5	4	.....
D	5	2	3	1	4	.....
E	1	4	5	2	3	.....
F	5	3	1	2	4	.....
G	2	4	3	1	5	.....
H	5	3	1	4	2	.....
I	5	1	2	4	3	.....
J	4	5	3	1	2	.....
Total	34	32	28	23	33	.....

SUMMARY OF RESULTS OF HAM-CURING EXPERIMENTS.

1. Eighteen tierces of hams were cured at four establishments.

2. The extent of the absorption of the curing materials by the hams does not bear any relation to the kind of sugar used.

3. As an average of the results obtained at establishments A, B, and C it was found that the old pickle from the cured hams contained 63.4 per cent of the sodium chlorid, 64.83 per cent of the sodium nitrate, and 71.56 per cent of the sugar present in the new pickle. From the standpoint of economy the importance of making use of the old pickle, on account of the curing materials which it contains, is evident.

4. Five sour hams, three of which were classed as light shank sours, one of a light aitchbone sour, and one a shank sour, were found in a total of 518 hams cured. One sour ham was found in a tierce cured with dextrose, two in tierces cured with cerelose, one in a tierce cured with 70 per cent corn sugar, and one in a tierce cured with raw sugar. These data do not necessarily indicate the percentage of sour hams which might be expected in the practical curing of hams with the several sugars on a large scale. Such information can be obtained only by extended practical use of the sugars.

5. The average relative quality of the hams cured with the several sugars at the four establishments can not be indicated with a high degree of accuracy, since not all the sugars were used at each establishment. However, a careful consideration of the reports on the quality of the hams cured at each plant indicates that the hams should be ranked in approximately the following order, according to the kind of sugar used: First, granulated sugar; second, raw sugar; third, cerelose; fourth, dextrose; fifth, refiners' sirup; sixth, 70 per cent corn sugar. There really was very little difference in the quality of the first five lots of hams, and even the sixth lot, cured with 70

per cent corn sugar, was considered to be of good quality. In fact, in the experiment carried on at establishment B the hams cured with this sugar ranked first.

EXPERIMENTS WITH SWEET-PICKLE BACON.

Experiments with sweet-pickle bacon were carried on at each of the four establishments, but, as with the hams, the one at establishment X was of a preliminary nature. In all, 19 tierces of bellies were cured.

PRELIMINARY EXPERIMENT AT ESTABLISHMENT X.

Three tierces of bellies were cured at establishment X, one with granulated sugar, one with cerelose, and one without sugar. The chilled bellies were packed in tierces as follows: Tierce 1: Sixty-one bellies were packed together with 8 ounces of sodium nitrate, 10 pounds of salt, and 4½ pounds of granulated sugar, the curing materials being sprinkled over the faces of the bellies. Tierce 2: Fifty-five bellies were packed with the above quantities of salt and sodium nitrate and with 4½ pounds of cerelose. Tierce 3: Fifty-five bellies were packed with the same quantities of salt and sodium nitrate, but without sugar. The tierces were held 48 hours in a curing cellar at 35°–37° F., then filled with plain 70° brine, and held at the same temperature until cured. The tierces were rolled on the fifth, fifteenth, and thirtieth days after packing. The cured bellies were inspected for soundness, soaked 5 hours in water, and smoked 13 hours. No unsound bellies were found. Two smoked bellies were selected from each lot for test purposes. In Table 9 is presented a brief record of the experiment.

TABLE 9.—*Record of preliminary sweet-pickle bacon experiment, establishment X.*

Item.	Tierce 1, granulated sugar.	Tierce 2, cerelose.	Tierce 3, no sugar.
Number of bellies	61	55	55
Curing period ... days	33	33	33
Weight of cured bellies ... pounds	410	425	415
Condition of cured bellies	Normal.	Normal.	Normal.

QUALITY OF THE SWEET-PICKLE BACON.

The relative quality of the three lots of bacon was judged upon the basis of the appearance of the freshly cut surface of the bacon and upon the appearance, texture, and palatability of the fried or broiled product. The three lots of bacon were tested by 12 individuals, 6 of whom determined the quality of the bacon in their homes, while the other 6 attended a test held in the laboratory. In

this and subsequent tests made in this laboratory each lot of bacon was fried in a clean frying pan over a low flame and in as nearly the same manner as possible as each of the other lots. A summary of the reports of the judges is presented in Table 10.

TABLE 10.—*Quality of sweet-pickle bacon (preliminary experiment at establishment X.)*

Judge.	Tierce 1, granulated sugar.	Tierce 2, cerelose.	Tierce 3, no sugar.
	Points.	*Points.*	*Points.*
A	2	3	1
B	3	2	1
C	2	3	1
D	1	3	2
E	3	2	1
F	3	1½	1½
G	1½	1½	3
H	3	1	2
I	3	1	2
J	3	2	1
K	2	3	1
L	2	3	1
Total	28½	26	17½

Basis for scoring: First choice, 3 points; second choice, 2 points; third choice, 1 point. The result of the test indicates that there was very little difference in the quality of the bacon cured with granulated sugar as compared with that cured with cerelose, but that the bacon cured without sugar was of appreciably lower quality. This lot of bacon did not brown on frying and the flavor was distinctly inferior to that of the two other lots.

EXPERIMENTS AT ESTABLISHMENTS A, B, AND C.

PLAN OF WORK.

Six tierces of bellies were cured at establishment A, and 5 each at establishments B and C.

At each establishment the chilled bellies were packed in tierces which were then filled with pickles made up according to the same formula except as regards the kind of sugar used. Raw sugar was being used at the time in curing this class of meat at establishment A, and refiners' sirup at establishment B. The tierces were stored during the curing period at a temperature approximating 36°–37° F. at establishments A and B, and at a temperature of 40° F. at establishment C. The tierces were rolled on the fifth and fifteenth days after packing.

At establishment A the cured bellies were soaked 1¼ hours in water at 70° F. and were smoked 30 hours at a temperature of 130°–135° F. At establishment B the bellies were due to be cured in 30 days but by a mistake were left in cure 48 days. The cured bellies were soaked

2 hours and 20 minutes in water at 70° F. and were smoked 18 hours at a temperature approximating 100° F. At establishment C the cured bellies were soaked 1½ hours in water at 60° F. and were smoked 18 hours at 120°–130° F. The smoked bellies were inspected for soundness by a Government inspector. A record of the experiments is shown in Table 11.

TABLE 11.—*Record of sweet-pickle bacon experiments at establishments A, B, and C.*

Item.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
ESTABLISHMENT A.						
Number of bellies	34	34	33	35	34	35
Curing period ... days	26	26	26	26	26	26
Weight of green bellies ... pounds	300	300	300	300	300	300
Weight of cured bellies ... do	336	330	331	330	332	331
Gain in weight ... do	36	30	31	30	32	31
Quantity of pickle ... gallons	17	16½	18½	16	14	16
Condition of smoked bellies	Normal.	Normal.	Normal.	Normal.	Normal.	Normal.
ESTABLISHMENT B.						
Number of bellies	24	26	26	25	26	.....
Curing period ... days	48	48	48	48	48	.....
Weight of green bellies ... pounds	280	280	280	280	280	.....
Weight of cured bellies ... do	330	328	320	328	328	.....
Gain in weight ... do	50	48	40	48	48	.....
Quantity of pickle ... gallons	17	20	17½	18	18	.....
Condition of smoked bellies	Normal.	Normal.	Normal.	Normal.	Normal.	.....
ESTABLISHMENT C.						
Number of bellies	26	26	26	26	26	.....
Curing period ... days	34	34	34	34	34	.....
Weight of green bellies ... pounds	280	280	280	280	280	.....
Weight of cured bellies ... do	310	310	305	305	305	.....
Gain in weight ... do	30	30	25	25	25	.....
Quantity of pickle ... gallons	17	17	17	17	17	.....
Condition of smoked bellies	Normal.	Normal.	Normal.	Normal.	Normal.	.....

COMPOSITION OF PICKLE.

The composition of the new and old pickle from each tierce of bellies is shown in Table 12.

TABLE 12.—*Composition of new and old bacon pickle.*

ESTABLISHMENT A.

Tierce No.	Age of pickle.	Kind of sugar.	Specific gravity at 20° C.	Salometer reading at 20° C.	Sodium chlorid.	Sodium nitrate.	Total sugar.
	Days.			*Degrees.*	*Per cent.*	*Per cent.*	*Per cent.*
1	New.	Granulated	1.139	70	16.70	0.49	1.78
1	26	....do	1.090	46	10.21	.29	1.36
2	New.	Dextrose	1.139	70	16.70	.53	1.76
2	26	....do	1.090	46	10.31	.36	1.22
3	New.	Cerelose	1.141	71	16.67	.54	1.71
3	26	....do	1.094	48	10.75	.36	1.20
4	New.	70 per cent corn sugar	1.136	68	16.40	.53	1.87
4	26	....do	1.090	46	10.04	.34	1.32
5	New.	Refiners' sirup	1.138	69	16.57	.53	1.77
5	26	....do	1.093	48	10.32	.36	1.32
6	New.	Raw	1.137	69	16.80	.53	1.71
6	26	....do	1.090	46	10.62	.36	1.33

TABLE 12.—*Composition of new and old bacon pickle*—Continued.

ESTABLISHMENT B.

Tierce No.	Age of pickle.	Kind of sugar.	Specific gravity at 20° C.	Salometer reading at 20° C.	Sodium chlorid.	Sodium nitrate.	Total sugar.
	Days.			*Degrees.*	*Per cent.*	*Per cent.*	*Per cent.*
1	New.	Granulated	1.152	76	18.72	0.29	1.44
1	45	do	1.110	57	13.12	.13	1.13
2	New.	Dextrose	1.152	76	18.72	.44	1.45
2	45	do	1.111	57	13.40	.26	1.25
3	New.	Cerelose	1.156	78	19.43	.26	1.37
3	45	do	1.116	59	14.18	.20	.90
4	New.	70 per cent corn sugar	1.152	76	18.55	.26	1.52
4	45	do	1.110	57	13.07	.17	1.11
5	New.	Refiners' sirup	1.156	78	18.17	.24	2.45
5	45	do			12.81	.19	1.87

ESTABLISHMENT C.

1	New.	Granulated	1.140	70	17.42	0.24	0.86
1	27	do	1.105	54	9.65		
2	New.	Dextrose	1.139	70	17.44	.23	.82
2	27	do	1.098	50	9.52		.65
3	New.	Cerelose	1.139	70	17.46	.21	.81
3	27	do	1.097	49	9.52	.17	.64
4	New.	70 per cent corn sugar	1.140	70	17.47	.22	.84
4	27	do	1.099	50	9.61		.61
5	New.	Refiners' sirup	1.142	72	17.65	.24	.89
5	27	do	1.101	51	9.87		.72

Table 13 shows the relative composition of the new and old pickle from each tierce, based upon 100 parts of each curing material in the new pickle. The data from establishment A indicate comparatively small differences in the relative composition of the old pickle from the several tierces as compared with the composition of the new pickle. The old pickles from the tierces cured with corn sugar contain slightly less sugar than those from the tierces cured with cane sugars. The data indicate that on the average the old pickle contains 62.59 per cent of the salt, 65.62 per cent of the sodium nitrate, and 73.14 per cent of the sugar originally present in the new pickle. At establishment B there are considerable differences in the relative nitrate and sugar contents of the old pickles from several of the tierces, but the significance of these variations is not apparent. The data at this establishment indicate that on the average 71.12 per cent of the salt, 65.08 per cent of the sodium nitrate, and 75.96 per cent of the sugar originally present in the new pickle were present in the old pickle from the cured bacon.

An average of the data at establishment C indicates that 55 per cent of the salt and 77.39 per cent of the sugar originally present in the new pickle were found in the old pickle at the end of the curing period.

TABLE 13.—*Relative composition of new and old bacon pickle at establishments A, B, and C.*

Constituent.	Age of pickle.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
		ESTABLISHMENT A.					
	Days.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00	100.00
Do	26	61.14	61.74	64.49	61.22	62.28	63.21
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00	100.00
Do	26	59.18	67.92	66.66	64.15	67.92	67.92
Total sugar	New.	100.00	100.00	100.00	100.00	100.00	100.00
Do	26	76.40	69.32	70.18	70.59	74.58	77.77
		ESTABLISHMENT B.					
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	45	70.08	71.58	72.98	70.46	70.50	.....
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	45	44.83	59.09	76.92	65.39	79.17	.....
Total sugar	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	45	78.47	86.27	65.69	73.03	76.33	.....
		ESTABLISHMENT C.					
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00	.....
Do	27	55.39	54.59	54.52	55.01	55.92	.....
Sodium nitrate	New.	.....	.....	.....	.....	.....	.....
Do	27	.....	.....	.....	.....	.....	.....
Total sugar	New.	.....	100.00	100.00	100.00	100.00	.....
Do	27	.....	79.27	79.14	70.24	80.90	.....

COMPOSITION OF THE BACON.

Table 14 shows the composition of the several lots of bacon bellies.

TABLE 14.—*Composition of sweet-pickle bacon at establishments A, B, and C.*

Constituent.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
	ESTABLISHMENT A.					
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	15.34	26.04	24.91	17.82	15.68	22.43
Sodium chlorid	3.62	3.15	3.90	2.78	2.36	3.74
Sodium nitrate	.09	.09	.10	.07	.06	.09
Total sugar	.33	.28	.36	.27	.19	.19
	ESTABLISHMENT B.					
Moisture	19.72	25.73	23.10	23.86	24.37	.....
Sodium chlorid	3.81	4.61	3.88	4.24	4.14	.....
Sodium nitrate	.04	.07	.04	.05	.06	.....
Total sugar	.27	.30	.23	.41	.32	.....
	ESTABLISHMENT C.					
Moisture	17.51	16.56	16.07	15.88	15.84	.....
Sodium chlorid	2.42	2.98	2.86	2.60	2.46	.....
Sodium nitrate	.05	.06	.05	.05	.05	.....
Total sugar	.16	.18	.16	.11	.35	.....

QUALITY OF THE BACON.

The quality of the bacon was judged upon the basis of the appearance of the freshly cut surface of the meat and of the appearance and palatability of the fried product. The bacon was cut in thin slices, and all lots were fried in as nearly the same manner as possible. Table 15 indicates the relative quality of the several lots of bacon.

At establishment A the basis for scoring was: First choice, 6 points; second choice, 5 points, etc. From the data in Table 15 it is apparent that in the official test the three lots of bacon cured with corn sugars were judged to be of appreciably higher quality than the other lots cured with cane sugars or refiners' sirup. Also, the lot of bacon which ranked highest was the one cured with 70 per cent corn sugar. It was noted that the bacon cured with corn sugars browned more readily on frying than that cured with cane sugar or refiners' sirup. In the plant test at this establishment the results indicate that the bacon cured with cane sugar and refiners' sirup was superior in quality to that cured with the corn sugars. These findings are directly the opposite of those obtained in the official test on the same lots of bacon.

It was noted in the establishment test that the bacon cured with corn sugar had a very dark and burnt appearance after frying. An average of the official and plant tests results in: First choice, tierce 1, granulated sugar, 66 points; second choice, tierce 4, 70 per cent corn sugar, 63 points; third choice, tierce 2, dextrose, 62 points; fourth choice, tierce 3, cerelose, 58 points; fifth choice, tierce 6, raw sugar, 56 points, and sixth choice, tierce 5, refiners' sirup, 53 points.

The basis for scoring at establishments B and C was: First choice, 5 points; second choice, 4 points, etc. The data indicate that at establishment B the bacon cured with dextrose was considered to be of the highest quality, followed in turn by that cured with cerelose, 70 per cent corn sugar, granulated sugar, and refiners' sirup. All lots of bacon at establishment B were considered to be too salty, which is due to the fact that the bellies were held in cure too long, as has been previously noted.

At establishment C the bacon cured with dextrose, cerelose, and refiners' sirup, respectively, was of practically the same quality, while that cured with graulated sugar and 70 per cent corn sugar was of slightly lower quality. On frying, the bacon which had been cured with corn sugar browned nicely while that cured with granulated sugar or refiners' sirup turned yellow.

Establishment C conducted a test on the quality of the sweet-pickle bacon and reported that there was practically no difference in the

flavor of the several lots of bacon but appreciable difference in the appearance of the product on frying. The lots of bacon were ranked in the following order according to the kind of sugar used: First, sirup; second, granulated sugar; third, 70 per cent corn sugar; fourth, cerelose; fifth, dextrose.

TABLE 15.—*Quality of sweet-pickle bacon at establishments A, B, and C.*

Judge.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.	Tierce 6, raw sugar.
	Points.	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*
ESTABLISHMENT A (OFFICIAL TEST).						
A	3	4	5	6	1	2
B	3	5	4	6	2	1
C	3	5	4	6	1	2
D	3	5	4	6	2	1
E	3	5	4	6	2	1
F	3	5	4	6	2	1
G	3	4	5	6	1	2
H	3	4	5	6	2	1
I	3	5	4	6	1	2
Total	27	42	39	54	14	13
ESTABLISHMENT A (PLANT TEST).						
M	4	3	2	1	5	6
N	5	1	3	2	4	6
O	6	2	3	1	5	4
P	6	3	2	1	4	5
Q	4	3	2	1	5	6
R	6	2	3	1	4	5
S	4	3	2	1	5	6
T	4	3	2	1	6	5
Total	39	20	19	9	38	43
ESTABLISHMENT B.						
A	4	5	3	1	2	.....
B	2	5	4	3	1	.....
C	3	5	4	2	1	.....
D	1	3	2	5	4	.....
E	3	5	4	2	1	.....
F	3	5	4	2	1	.....
G	3	5	4	1	2	.....
H	1	5	3	4	2	.....
I	3	5	2	4	1	.....
Total	23	43	30	24	15	.....
ESTABLISHMENT C.						
A	2	3	4	1	5	.....
B	4	5	2	1	3	.....
C	1	4	3	5	2	.....
D	2	4	5	1	3	.....
E	5	2	3	4	1	.....
F	2	3	4	1	5	.....
G	1	2	3	4	5	.....
H	3	5	1	2	4	.....
I	1	4	5	3	2	.....
Total	21	32	30	22	30	.....

SUMMARY OF RESULTS OF SWEET-PICKLE BACON EXPERIMENTS.

1. Nineteen tierces of bellies were cured in four establishments.

2. The corn sugars were absorbed as completely by the meat during the process of curing as was the cane sugar.

3. As an average of the results obtained at establishments A, B, and C, it appears that the old pickle from the cured bellies contained 64.57 per cent of the salt, 65.75 per cent of the sodium nitrate, and 75.50 per cent of the sugar originally present in the new pickle. The waste of curing materials occasioned by throwing away the old pickle from sweet-pickle bellies is apparent.

4. No unsound bacon was found in any of the tests.

5. The quality of the bacon cured with the several sugars did not differ widely. As an average of the results of the tests conducted at establishments A, B, and C, it appears that the bacon should be ranked in approximately the following order, according to the kind of sugar used: First, dextrose; second, cerelose; third, 70 per cent corn sugar; fourth, granulated sugar; and, fifth, refiners' sirup.

EXPERIMENTS WITH BOX-CURED BACON.

A large proportion of the fancy breakfast bacon on the market is cured by the so-called "box-cure" method. The bellies cured in this way are especially selected for quality and size and are trimmed to rectangular form. The chilled bellies are packed in specially made metal-lined wooden boxes provided with hinged, tight-fitting covers. The boxes are usually lined with waxed paper before packing with bacon. The bottom is sprinkled with a thin covering of the curing mixture consisting of salt, sugar, and sodium nitrate, and a layer of bacon bellies is then carefully packed on the bottom, flesh side up, and a thin covering of the curing mixture is sprinkled over the meat. Successive layers of bacon and curing mixture are packed until the box is filled. The top layer is finally covered with paper and the cover is fitted into place with the aid of pressure. A definite weight of bacon and curing mixture is packed in each box. The capacity of the boxes used by different establishments varies. Some establishments use boxes holding approximately 625 pounds; others have boxes holding 1,000 pounds. Bacon cured in this way is not overhauled. The curing mixture abstracts moisture from the meat and before the end of the curing period the bellies should be entirely covered with the pickle formed in this way.

PLAN OF WORK.

The experiments with box-cured bacon were carried on at establishments A, B, and C, three boxes of bacon being cured at each plant. Granulated sugar, dextrose, and cerelose were the sugars used. A brief record of the experiments is presented in Table 16.

The same quantities of salt, sodium nitrate, and sugar were used in each box at a single establishment, correction being made for the impurities present in the cerelose. At establishment A the boxes were stored during the curing period in a curing cellar at a temperature of 36°–37° F. The cured bellies were soaked one hour in water at 70° F. and were smoked 30 hours at 130°–135° F. At establishment B the boxes were stored in a curing cellar at a similar temperature and the cured bellies were soaked 10 minutes in water at 70° F. and smoked 18 hours at 100° F. At establishment C the boxes were stored in a curing cellar at a temperature of approximately 40° F. and the cured bellies were soaked one hour in water at 60° F. and were smoked 20 hours at 116° F.

TABLE 16.—*Record of box-cured bacon experiments at establishments A, B, and C.*

Item.	Box 1, granulated sugar.	Box 2, dextrose.	Box 3, cerelose.
ESTABLISHMENT A.			
Number of bellies	80	84	83
Curing period ... days	21	21	21
Weight of green bellies ... pounds	625	625	625
Weight of cured bellies ... do	627	630	627
Gain in weight ... do	2	5	2
Condition of smoked bellies	Normal.	Normal.	Normal.
ESTABLISHMENT B.			
Number of bellies	46	48	46
Curing period ... days	24	24	24
Weight of green bellies ... pounds	300	300	300
Weight of cured bellies ... do	303	304	305
Gain in weight ... do	3	4	5
Condition of smoked bellies	Normal.	Normal.	Normal.
ESTABLISHMENT C.			
Curing period ... days	24	24	24
Weight of green bellies ... pounds	575	575	575
Weight of cured bellies ... do	571	572	572
Loss in weight ... do	4	3	3
Condition of smoked bellies	Normal.	Normal.	Normal.

COMPOSITION OF BOX-CURED BACON.

The composition of the smoked bacon is shown in Table 17. Attention is called to the relatively low salt and high sugar and nitrate content of this bacon at establishment A, as compared with the sweet-pickle bacon cured in the same establishment. (See Table 14.) At establishment B may be noted the relatively high sugar content of the three lots of bacon, the average percentage of sugar being twice as great as that present in the box-cured bacon cured at establishment A, and over eight times as great as the average percentage of sugar present in the sweet-pickle bacon cured at the latter establishment. The figures for establishment C show a low salt and sodium-nitrate con-

tent of this bacon as compared with that cured at establishments A and B. There are considerable differences in the amounts of curing materials present in the three lots of bacon, but these variations do not appear to have any special significance. The average sugar content of the three lots of bacon is 0.55 per cent, as compared with 0.81 per cent in the bacon cured at establishment A, and 1.63 per cent in that cured at establishment B.

TABLE 17.—*Composition of box-cured bacon at establishments A, B, and C.*

Constituent.	Box 1, granulated sugar.	Box 2, dextrose.	Box 3, cerelose.
ESTABLISHMENT A.			
	Per cent.	*Per cent.*	*Per cent.*
Moisture	15.15	13.38	19.93
Sodium chlorid	2.40	1.75	2.46
Sodium nitrate	.20	.13	.16
Total sugar	1.02	.61	.81
ESTABLISHMENT B.			
Moisture	12.23	19.33	14.91
Sodium chlorid	2.46	2.60	2.52
Sodium nitrate	.29	.35	.27
Total sugar	1.82	1.82	1.26
ESTABLISHMENT C.			
Moisture	14.67	14.34	12.68
Sodium chlorid	1.77	.96	1.16
Sodium nitrate	.12	.03	.09
Total sugar	.77	.33	.56

QUALITY OF BOX-CURED BACON.

The relative quality of the bacon is shown in Table 18, the test being made in the manner previously described. The basis for scoring was: First choice, 3 points; second choice, 2 points, etc.

TABLE 18.—*Quality of box-cured bacon at establishments A, B, and C.*

Judge.	Establishment A (Official test).			Judge.	Establishment A (Plant test).		
	Box 1, granulated sugar.	Box 2, dextrose.	Box 3, cerelose.		Box 1, granulated sugar.	Box 2, dextrose.	Box 3, cerelose.
	Points.	*Points.*	*Points.*		*Points.*	*Points.*	*Points.*
A	1	3	2	M	3	1	2
B	1	2	3	N	3	1	2
C	1	3	2	O	3	1	2
D	2	3	1	P	3	1	2
E	3	1	2	Q	3	1	2
F	1	2	3	R	3	2	1
G	1	3	2	S	3	1	2
H	3	2	1	T	3	1	2
Total	13	19	16	Total	24	9	15

TABLE 18.—*Quality of box-cured bacon at establishments A, B, and C*—Contd.

Judge.	Establishment B.			Judge.	Establishment C.		
	Box 1, granulated sugar.	Box 2, dextrose.	Box 3, cerelose.		Box 1, granulated sugar.	Box 2, dextrose.	Box 3, cerelose.
	Points.	*Points.*	*Points.*		*Points.*	*Points.*	*Points.*
A	3	2	1	A	3	2	1
B	1	3	2	B	1	3	2
C	3	1	2	C	2	3	1
D	3	2	1	D	3	2	1
E	1	3	2	E	2	1	3
F	2	3	1	F	3	2	1
G	1	2	3	G	2	1	3
H	3	2	1	H	1	3	2
I	2	3	1	I	3	2	1
J	1	2	3	J	2	3	1
Total	20	23	17	Total	22	22	16

The results of the official test at establishment A indicate that when carefully broiled or fried the bacon cured with granulated sugar turned golden yellow in color—that is, the fatty tissue—while that cured with dextrose and cerelose turned light brown. Choice on the basis of appearance was largely a matter of personal taste. When fried too rapidly or too crisp, the bacon cured with the corn sugar had a tendency to turn dark-brown or to char. Under such conditions the bacon cured with granulated sugar was to be preferred. There was only a comparatively slight difference in the quality of the three lots of bacon, that cured with dextrose ranking first, with cerelose second, and with granulated sugar third.

In the plant test at establishment A the bacon cured with cane sugar was much preferred, particularly because it turned golden yellow in color on frying, whereas the bacon cured with corn sugars fried brown in color and charred readily. The officials stated that the bacon cured with dextrose and cerelose would not prove satisfactory on the market in competition with bacon cured with cane sugar.

The scoring of the bacon cured at establishment B indicates that there was very little difference in the quality of the three lots of bacon. As has been noted, the bacon cured with dextrose and cerelose browned more readily on frying or broiling than that cured with granulated sugar. There seemed to be very little difference in the flavor of the three lots of bacon, all being of high quality.

The results for establishment C show that the bacon cured with granulated sugar and that cured with dextrose were of practically the same quality, while that cured with cerelose was of only slightly lower quality. The bacon cured with corn sugar turned light brown on cooking, while that cured with granulated sugar turned yellow. All the bacon was considered to be of first-class quality.

The officials of establishment C conducted a cooking test on the three lots of bacon and reported that the samples were ranked as follows, according to the kind of sugar used in curing: First choice, granulated sugar; second choice, dextrose; third choice, cerelose. The bacon cured with corn sugar had a tendency to char on frying, while that cured with granulated sugar turned yellow. There seemed to be but little difference in flavor. It was considered that the use of corn sugar in place of cane sugar in curing this class of bacon would not yield a satisfactory bacon on account of the tendency of the product to turn brown or char on frying.

SUMMARY OF RESULTS OF BOX-CURED BACON EXPERIMENTS.

1. Nine boxes of bacon were cured in three establishments.
2. The average sugar content of the bacon cured with each of the three sugars was as follows: Granulated sugar, 1.20 per cent; dextrose, 0.92 per cent; cerelose, 0.88 per cent. This indicates a slightly greater absorption of granulated sugar than of corn sugar.
3. No unsound bacon was found in any of the tests.
4. The evidence as to the relative quality of the bacon cured with granulated sugar, dextrose, and cerelose is conflicting. A summary of the three tests conducted in the laboratory shows that the total number of points scored by each lot of bacon was as follows: Dextrose, 64; granulated sugar, 55; and cerelose, 49. All lots of bacon were considered to be of high quality. On the other hand, the tests conducted by officials of establishments A and C indicated a marked preference for the bacon cured with granulated sugar, that cured with dextrose ranking second, and with cerelose third. Objection was made to the bacon cured with corn sugar chiefly because the product browned too readily on frying and charred if cooked too rapidly or too crisp. It was considered that bacon cured with corn sugar by the box method would not be so desirable a product as that cured with granulated sugar.

The writer is of the opinion, notwithstanding these conflicting views, that the possibility that corn sugars can be used successfully in curing bacon by the box-cure method is not excluded, but that further experiments should be carried on in order to settle the question.

EXPERIMENTS WITH BEEF HAMS.

Beef hams are groups of muscles cut from the rounds of cattle. The hams are classed as insides, outsides, and knuckles, according to the part of the round from which they are cut. Beef hams are usually cut from the rounds of poorly finished medium or light-weight cattle. The hams are packed in tierces and cured in a pickle containing salt, sugar, and sodium nitrate. When cured the hams are soaked in water to remove excess salt and are then smoked and dried for several days. The dried-beef hams are finally cut into very thin slices, either at the packing house or in the retail meat shop,

before being sold to the consumer, who purchases the product as "chipped beef." High-grade "chipped beef" should be bright red in color, mildly salty, sweet, and of pleasing flavor. When properly cured, dried beef, either in the ham or chipped, should keep in good condition for a considerable time at ordinary temperatures.

PLAN OF WORK.

The experimental work was conducted at establishments A and B, five tierces of hams being cured at each plant. Granulated sugar, dextrose, cerelose, 70 per cent corn sugar, and refiners' sirup were the sugars used. The hams were cured according to the usual practice at each establishment except as regards the kind of sugar used. One tierce of hams was cured in pickle made up according to the formula regularly followed in the establishment, while each of the other tierces of hams was cured in pickle of like composition except that an equivalent amount of corn sugar, or of the sugar found in refiners' sirup, was substituted for the sugar regularly used.

The chilled beef hams ("insides") were packed in tierces which were then filled with pickle, but at establishment B 5 pounds of salt was sprinkled over the hams in each tierce when packed, and the tierce was then filled with pickle. The tierces were stored in a curing cellar at approximately 37° F. and were rolled on the fifth, fifteenth, and thirtieth days after packing. At establishment A the cured hams were soaked 9 hours in water at 70° F. and were smoked 6 days at 135° F. At establishment B the cured hams were soaked 20 hours in two changes of water at 65° F. with four overhaulings. The hams were smoked and dried five days at a temperature of 100°–110° F.

The smoked hams were inspected for soundness by a Government inspector. Two hams from each tierce were selected for test purposes. A brief record of the experiment is presented in Table 19.

TABLE 19.—*Record of beef-ham experiments at establishments A and B.*

ESTABLISHMENT A.

Item.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.
Number of hams	29	27	27	27	27
Weight of green hams ... pounds	330	330	330	330	320
Weight of cured hams ... do	362	355	375	374	354
Gain in weight ... do	32	25	45	44	34
Quantity of pickle ... gallons	13	13	12½	15	17¾
Condition of smoked hams	Normal.	Normal.	Normal.	One light sour.	One light sour.

ESTABLISHMENT B.

Number of hams	27	27	27	27	27
Weight of green hams ... pounds	320	320	320	320	320
Quality of pickle ... gallons	15	14	15	16	15
Condition of smoked hams	Normal.	Normal.	Normal.	Normal.	Normal.

The composition of the new and old pickle from each tierce is shown in Table 20.

TABLE 20.—*Composition of beef-ham pickle at establishments A and B.*

ESTABLISHMENT A.

Tierce No.	Age of pickle.	Kind of sugar.	Specific gravity at 20° C.	Salometer reading at 20° C.	Sodium chlorid.	Sodium nitrate.	Total sugar.
	Days.			*Degrees.*	*Per cent.*	*Per cent.*	*Per cent.*
1	New.	Granulated	1.190	94	23.10	0.67	1.58
1	90	do	1.082	42	8.52	.35	1.04
2	New.	Dextrose	1.190	94	23.15	.66	1.45
2	90	do	1.081	42	8.36	.....	.89
3	New.	Cerelose	1.190	94	23.15	.69	1.54
3	90	do	1.080	42	8.23	.34	.70
4	New.	70 per cent corn sugar	1.190	94	23.00	.69	1.66
4	90	do	1.087	44	9.07	.39	.85
5	New.	Refiners' sirup	1.193	95	22.90	.67	1.50
5	90	do	1.090	49	10.03	.39	1.07

ESTABLISHMENT B.

1	New.	Granulated	1.191	95	22.28	0.92	2.59
1	72	do	1.098	50	9.65	.31	.91
2	New.	Dextrose	1.200	98	23.75	.77	2.17
2	72	do	1.095	49	10.19	.21	.75
3	New.	Cerelose	1.200	98	23.54	.77	2.20
3	72	do	1.083	43	8.37	.18	.17
4	New.	70 per cent corn sugar	1.200	98	23.28	.81	2.65
4	72	do	1.104	53	11.32	.20	1.13
5	New.	Refiners' sirup	1.198	97	23.86	.78	2.51
5	72	do	1.100	49	10.34	.22	.64

Table 21 indicates the relative composition of the new and old pickle from each tierce based upon 100 parts of each constituent in the new pickle.

At establishment A it appears that relatively the smallest proportion of sugar in the form of cerelose remained in the old pickle from the cured hams, and the highest proportion of sugar from refiners' sirup. As an average of the data for each constituent remaining in the old pickle it appears that 38.35 per cent of the salt, 54.06 per cent of the sodium nitrate and 59.05 per cent of the sugar originally present in the new pickle was found in the old pickle.

In the consideration of the figures for sodium chlorid at establishment B it is to be remembered that 5 pounds of salt was added to each tierce of beef hams in addition to the salt present in the new pickle. The relative percentage of salt in the old pickle as compared with the new pickle does not, on this account, represent the true proportion of the salt, added to the fresh hams in dry form and in pickle, which remains in the old pickle.

TABLE 21.—*Relative composition of new and old beef-ham pickle at establishments A and B.*

Constituent.	Age of pickle.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.
ESTABLISHMENT A.						
	Days.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sodium chlorid	New.	100.0	100.00	100.00	100.00	100.00
Do	90	36.88	36.11	35.55	39.43	43.80
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00
Do	90	52.24	.....	49.28	56.52	58.21
Total sugar	New.	100.00	100.00	100.00	100.00	100.00
Do	90	65.82	61.38	45.55	51.20	71.33
ESTABLISHMENT B.						
Sodium chlorid	New.	100.00	100.00	100.00	100.00	100.00
Do	72	43.31	42.90	35.56	48.62	45.23
Sodium nitrate	New.	100.00	100.00	100.00	100.00	100.00
Do	72	33.69	27.30	23.37	24.69	28.21
Total sugar	New.	100.00	100.00	100.00	100.00	100.00
Do	72	31.27	34.56	7.73	42.64	25.50

COMPOSITION OF BEEF HAMS.

The composition of the dried and smoked beef hams is indicated in Table 22. Analyses were made of sections cut from the middle of each of two hams from each tierce. There are appreciable differences in the percentages of salt, sodium nitrate, and sugar present in the several lots of hams, but the significance of the figures is not apparent.

It may be noted that the sugar content of the hams cured with dextrose is appreciably lower, and that of the hams cured with cerelose very much lower than that of the other lots of hams. The evidence is not sufficient to allow any conclusion to be drawn. The sodium-nitrate content of the beef hams cured with granulated sugar and with dextrose is considerably lower than that of the other lots of hams.

TABLE 22.—*Composition of beef hams at establishments A and B.*

Constituent.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.
ESTABLISHMENT A.					
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	59.26	55.82	57.67	52.67	57.07
Sodium chlorid	8.26	8.74	9.02	9.15	9.73
Sodium nitrate	.19	.23	.36	.39	.34
Total sugar	.50	.33	.28	.49	.59
ESTABLISHMENT B.					
Moisture	53.29	54.96	55.38	53.63	52.76
Sodium chlorid	9.14	10.60	8.40	10.16	10.35
Sodium nitrate	.04	.04	.11	.19	.18
Total sugar	.69	.52	.11	.70	.79

QUALITY OF DRIED-BEEF HAMS.

The quality of the dried beef was judged from the appearance and palatability of thin slices of the beef cut from the middle portion of

each of two hams from each tierce. The dried beef was eaten without cooking. A report of the tests is shown in Table 23.

The result of this test at establishment A indicates that the beef hams cured with dextrose were of the highest quality, followed in turn by those cured with cerelose, granulated sugar, 70 per cent corn sugar, and refiners' sirup. Granulated sugar was being used regularly in curing beef hams at this establishment, and this grade of sugar is very generally used in curing beef hams. Thus it appears that the hams cured with two of the corn sugars, namely, dextrose and cerelose, were superior in quality to the hams cured with granulated sugar.

The results at establishment B indicate that the beef hams cured with granulated sugar were of the highest quality, closely followed by those cured with cerelose; the beef hams cured with dextrose and with 70 per cent corn sugar were of practically the same but of appreciably lower quality than those cured with either granulated sugar or cerelose, while the hams cured with refiners' sirup were of a decidedly lower quality, both as regards appearance and flavor.

TABLE 23.—*Quality of dried-beef hams at establishments A and B.*

ESTABLISHMENT A.

Judge.	Tierce 1, granulated sugar.	Tierce 2, dextrose.	Tierce 3, cerelose.	Tierce 4, 70 per cent corn sugar.	Tierce 5, refiners' sirup.
	Points.	*Points.*	*Points.*	*Points.*	*Points.*
A	5	1	4	2	3
B	2	5	4	3	1
C	3	5	4	1	2
D	1	4	5	2	3
E	1	5	2	4	3
F	3	5	4	2	1
G	3	5	4	2	1
H	4	5	3	2	1
Total	22	35	30	18	15

ESTABLISHMENT B.

A	5	3	2	4	1
B	3	1	5	4	2
C	5	2	4	3	1
D	4	3	5	2	1
E	5	2	4	3	1
F	4	5	3	2	1
G	5	2	4	3	1
H	4	3	5	2	1
I	2	5	3	4	1
Total	37	26	35	27	10

SUMMARY OF RESULTS OF CURING EXPERIMENTS WITH BEEF HAMS.

1. Ten tierces of beef hams were cured at two establishments.

2. Only one slightly sour beef ham was found in the two experiments, and that in a tierce cured with refiners' sirup.

3. Combining the results of the tests on the quality of the beef hams cured at the two establishments, the several lots of hams rank as follows according to the kind of sugar used: First choice, cerelose, 65 points; second choice, dextrose, 61 points; third choice, granulated sugar, 59 points; fourth choice, 70 per cent corn sugar, 45 points; fifth choice, refiners' sirup, 35 points. These facts indicate that dextrose and cerelose are at least equal in value to granulated sugar for use in curing beef hams, but refiners' sirup yielded a product of lower quality.

GENERAL SUMMARY.

1. The results of the experiments in curing pork hams indicate that the several sugar substitutes employed, viz, dextrose, cerelose, 70 per cent corn sugar, and refiners' sirup, can be used successfully in place of cane sugar in curing this class of meats. The difference in the quality of the hams cured with the several sugars was slight.

2. The results obtained in the curing of sweet-pickle bacon with the sugar substitutes named, as compared with cane sugar, were similar to those obtained with pork hams. There was comparatively little difference in the quality of the bacon cured with the different sugars. However, the bacon cured with the three corn sugars was considered to be of slightly better quality than that cured with cane sugar or refiners' sirup.

3. The experiments with box-cured bacon yielded conflicting results. The tests on the quality of the bacon conducted by the department indicated that there was little difference in the quality of the bacon cured with dextrose and cerelose as compared with that cured with cane sugar. On the other hand, the tests conducted by two of the establishments indicated that bacon cured with cane sugar was of distinctly superior quality, chiefly because the bacon cured with corn sugars browned too readily on frying. In view of these conflicting opinions, further experiments in the use of corn sugars in curing box-cured bacon are desirable.

4. In the curing experiments with beef hams, the use of dextrose and cerelose yielded dried beef of as good quality as that obtained by the use of cane sugar. The beef hams cured with 70 per cent corn sugar and with refiners' sirup were of inferior quality.

5. The experiments reported in this paper must be regarded as of a preliminary nature, and while the results indicate strongly that several corn sugars, as well as refiners' sirup, can be used successfully as substitutes for cane sugar (sucrose) in curing meats, yet it is highly advisable that meat-packing establishments contemplating the use of one or more of these substitutes first conduct curing tests on a moderate scale before curing large quantities of meat with the sugar substitutes chosen.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 929

Contribution from the Bureau of Animal industry
JOHN R. MOHLER, Chief

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COTTONSEED MEAL FOR HORSES.

By G. A. Bell and J. O. Williams, *Animal Husbandry Division.*

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OUTPUT AND USES OF COTTONSEED MEAL.

COTTONSEED MEAL is the ground cake left after the oil has been extracted from cotton seed. It is the most important by-product obtained in the manufacture of cottonseed oil, forming more than one-half of the total products obtained from the cotton seed. Approximately 2,500,000 tons of cottonseed meal and cake were produced in 1919, having a valuation of over $150,000,000. Of the quantity produced, somewhat more than 300,000 tons were exported, leaving more than 2,000,000 tons for home consumption.

Cottonseed meal is used as a fertilizer and as a feed for livestock. Its value as cattle feed is well established, but, owing to prejudices which have existed among horse feeders, cottonseed meal has not been held in favor as a feed for work stock. Feeders assert that it is likely to produce digestive disorders and that it can not be fed with safety. These claims, no doubt, have some foundation, but the harmful results have usually followed the use of a poor quality of meal or the feeding of excessive quantities.

Cottonseed meal is a heavy protein concentrate and its use as a supplement to the ration of work stock in supplying the protein content would be highly desirable, if safe. The test reported in this bulletin was conducted to determine to what extent cottonseed meal may be fed to horses with safety.

PREVIOUS EXPERIMENTS IN FEEDING COTTONSEED MEAL TO HORSES.

Iowa State Bulletin 109 reports results of feeding trials lasting two years and in which concentrated feeds rich in protein were substituted for oats in rations for work horses. Among the conclusions drawn is the following:

"The health, spirit, and endurance of work horses were the same when fed corn with a moderate amount of * * * cottonseed meal as when fed a corn and oats ration, supplying a similar nutritive ratio.

North Carolina Station Bulletin 215 reports the results of experiments conducted to determine the possibility of using cottonseed meal successfully in rations for work horses, the form and combination in which it may best be fed, and the harmful effects, if any, resulting from its use. The author states that in each case where cottonseed meal was fed the coat of the animal became smoother and glossier than usual, that the spirit and endurance were not lessened, and that at the end of the experiment no harmful effects could be found as a result of feeding the meal. Farmers are advised not to feed draft animals cottonseed meal to the extent of more than 10 to 15 per cent by weight of the total ration.

The North Carolina Station Report for the year 1916 states the results of feeding cottonseed meal to work horses and mules at the Iredell, Pender, and Edgecombe substations. It was found that:

While cottonseed meal can be used in very limited amount, we can not, as a rule, induce a horse or mule to use more than 1 pound a day for any length of time. This 1 pound, however, has proved to be an economical addition to the ration and has also had much to do with maintaining the horses and mules in better condition.

THE EXPERIMENTAL FEEDING.

OBJECTS OF EXPERIMENT.

The objects of the experiment were:

1. To determine the value of cottonseed meal as a partial substitute for grain in a ration.
2. To determine the amount of cottonseed meal which can be fed with safety to work horses.

HORSES USED.

Sixteen horses were used in this experiment. With the exception of 4 purebred Morgans used for riding and driving, they were purebred and grade Percherons.

Of the 16 horses, 7 were not fed any cottonseed meal, thus acting as check animals. Where horses worked in teams it was planned to

have one check horse and one meal-fed horse work together. The work performed involved practically all kinds of farm labor. The Morgan horses performed rather severe work under saddle or in harness, as they were ridden and driven at considerable speed when at work. The Percherons were used in all routine farm work, which at rush periods was very heavy. All the horses were in splendid condition at the beginning of the experiment except the 2-year-old draft filly Castanette, which was not very thrifty, owing to a defective molar tooth.

On account of the wide variety of work and the individuality of the horses, no fixed ration was used, but the animals were fed as cheap a ration as seemed practicable under the prevailing conditions.

FEEDS USED.

The horses seemed to dislike the taste and odor of cottonseed meal. To overcome this aversion the meal was mixed with wheat bran. Only fresh, finely ground, sweet cottonseed meal was used at all times and it was thoroughly mixed with the wheat bran. Whole oats were used as the principal grain in the ration, supplemented with the wheat bran and cottonseed meal. Because of the defective tooth the filly Castanette was fed ground oats instead of whole oats. The roughage fed was a good grade of timothy hay, and the quantity varied with the appetites of the animals.

The following table shows the weights of the animals and the rations fed at the beginning of the experiment, October 1, 1917:

Daily rations of horses at beginning of experiment.

Horse.	Weight.	Ration.			
		Oats.	Timothy hay.	Wheat bran.	Cotton-seed meal.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pound.*
Stanley	1,510	15	18	3	¼
Virginia	1,500	18	18	3	.....
Maude	1,520	20	20	3	¼
Myrtle	1,475	15	15	3	.....
Nell	1,443	18	20	3	¼
Queen	1,295	18	18	3	.....
Bertina	1,520	20	18	3	¼
Fauna	1,770	27	20	3	.....
Pet	1,325	15	16	3	¼
June	1,250	15	12	3	¼
May	1,315	15	16	3	.....
Castanette	1,260	15	18	3	¼
Gladstone	965	8	10	3	¼
Georgia	965	10	10	3	.....
Brown Bess	970	15	12	3	¼
Evarts	995	8	10	3	.....

DETAILS OF EXPERIMENT.

The quantity of cottonseed meal fed was increased from a quarter to half a pound at the end of the first week. The horses ate their rations satisfactorily, but did not seem to have a keen appetite for the cottonseed meal. Owing to their apparent dislike for the cottonseed meal, the rations remained unchanged until November 12, when the quantity of cottonseed meal was increased to three-quarters of a pound a day. This quantity was continued until December 8 with satisfactory results.

On December 9 the quantity of cottonseed meal used was increased to 1 pound a day, and that quantity was fed until January 20, when it was increased to 1¼ pounds. With this increase the animals were each receiving one-half pound of the meal in the morning and evening and one-quarter pound at the noon feed.

On February 10 the quantity of cottonseed meal was further increased to 1½ pounds each per day and on February 17 to 1¾ pounds each per day. The quantity of cottonseed meal remained at this point until March 10, when it was again increased to 2 pounds a day each and the wheat bran was taken out of the ration. Until that time the animals had not shown any great dislike for the cottonseed meal.

On March 24 and thereafter the horse Gladstone continually refused the meal, so the amount fed to him was gradually reduced.

On April 7 the mare Nell refused to eat part of the morning and noon feeds. She continued to do this until April 22, when she refused her grain ration altogether and had slight colic attacks for two days. The meal was then taken out of her ration for the remainder of the month.

From April 15 to 27 the mares Maude, Stanley, June, and Brown Bess showed some dislike for the meal and left small portions of it at times during that period, and their droppings were of a hard and dry nature. During the last three days of the month these mares regained their normal appetites and consumed their feed as earlier in the experiment.

Pet, Bertina, and Castanette consumed their rations better than the other mares, always having a good appetite and seeming to relish the meal, a manifestation not shown by the others. These three mares, with Brown Bess, thrived very well on the cottonseed meal, all eating 2 pounds a day each during May. On May 27 the first three animals were given an increase of one-quarter pound a day, so that they were receiving 2¼ pounds of meal a day, divided into three equal feeds. The mares ate this quantity of meal very well and did not show any ill effects from its consumption.

On May 19 and thereafter the draft mares were turned out on Sundays and did not receive any grain or cottonseed meal on those

days. Commencing May 22, they were turned out at night and were then fed only one-half as much roughage as before.

On May 27 the cottonseed meal was taken out of the ration for Gladstone and Maude, as these two animals continually refused to eat grain containing the meal.

On June 3 the amount of cottonseed meal for the mares Pet and Castanette was increased to 2½ pounds a day.

The mares Nell, June, and Brown Bess did not appear to relish their grain ration containing cottonseed meal during the first week in June.

The mare Bertina died on June 4 from an attack of pneumonia. She was getting 2¼ pounds of cottonseed meal prior to her death, and had shown no ill effects from consuming this large amount. The death of this mare was not attributed to the feeding of cottonseed meal.

Maude and Gladstone were started on the cottonseed-meal ration again on June 10, each being fed one-half pound a day during the week. Maude ate the ration satisfactorily, but Gladstone refused to eat it.

Commencing June 16, Maude's allowance of cottonseed meal was increased to 1 pound a day and the meal taken out of Gladstone's ration, as he continued to refuse a ration containing meal.

The mares receiving cottonseed meal ate their grain containing it very well during the latter half of June.

The following table shows the weights of the animals and rations fed during the last period of the experiment, beginning August 31, 1918.

Daily rations of horses during last period of experiment.

Horse.	Weight, Aug. 31, 1918.	Ration.				
		Corn.	Oats.	Oat hay.	Wheat bran.	Cotton-seed meal.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Stanley	1,425	.....	18	16	.....	2
Virginia	1,570	.....	12	8	3	.....
Maude	1,670	10	.....	10	.....	1½
Myrtle	1,475	.....	12	8	3	.....
Nell [1]	1,485	.....	6	8	2	.....
Queen	1,410	.....	12	8	3	.....
Fauna	1,780	.....	15	10	3	.....
Pet	1,480	10	.....	8	.....	3
June	1,375	.....	16	16	.....	1½
May	1,390	.....	18	16	3	.....
Castanette	1,440	.....	12	8	.....	3
Gladstone	950	.....	10	10	2	.....
Georgia	960	.....	8	10	2	.....
Brown Bess	940	.....	10	10	.....	2
Evarts	940	.....	12	10	2	.....

[1] Foaled colt Aug. 28.

The mare Pet died on September 8 after a sudden attack of colic. After her death and one serious case of colic (Nell, referred to later), the feeding of cottonseed meal to all animals was discontinued for 30 days. During that period there was no noticeable change in the condition of the horses, nor were there any great changes in their weights.

The mare Nell was getting 1½ pounds of cottonseed meal up to August 28, on which date she gave birth to a foal. The feeding of cottonseed meal to this mare was discontinued at this time and was not resumed. This mare died September 25 from an attack of colic, and her death was not attributed to the cottonseed meal.

On October 6 the feeding of cottonseed meal was resumed, the amount of meal fed being 1 pound a day to each horse. It was thought that as the horses had eaten a much heavier ration of meal than that, 1 pound a day would have no harmful effects. On the second night after the horses were put back on the meal the mare Maude became very sick with a case of colic. As she had been quite healthy previous to that time, it was assumed that the cottonseed meal had caused the attack, so the meal was discontinued. She has shown no symptoms of sickness since.

On the sixth night after the renewal of the cottonseed-meal ration, the mare Stanley became quite sick with colic. The conditions in this case were very similar to those of the mare Maude. After having these two serious cases of colic, apparently caused from feeding the cottonseed meal, the feeding of this concentrate was discontinued, and the test ended October 13.

INDIVIDUAL CASES.

PET.

The young mare Pet was doing well on cottonseed meal and with Castanette was placed on a heavy cottonseed-meal ration. Pet received 3 pounds of cottonseed meal daily for 46 days. On September 7, 1918, she was taken with a severe case of colic and died the following morning. Before the attack she had been healthy and had shown no symptoms of colic. Post-mortem examination showed the stomach and intestines to be very much inflamed. There was a considerable quantity of cottonseed meal in the stomach and intestines. In this case indications were that death was due to the effects of cottonseed meal on the system. The harmful effects were not noticeable, however, until too late to prevent the loss of the mare.

NELL.

On September 25, 1918, the mare Nell had a severe case of colic from which she died the following day. This was one of many

frequent attacks to which she had been subject. A post-mortem examination showed malformation of the small intestine. A pocket had been formed in the intestine wall, which rendered the passage of food quite difficult. The frequent attacks of colic were no doubt due to stoppage of feed in the pocket of the intestine. At the time of death this pocket contained about a gallon of rather solid refuse. The death of the mare could not be attributed directly to the effects of cottonseed meal, as she had not been eating meal since August 28, at which time she gave birth to a foal.

SUMMARY OF EXPERIMENT.

The following table gives a brief summary of the experiment, showing the weights of various animals at the beginning of the test and the last weights, gain or loss in weight, quantities of cottonseed meal consumed, and a condensed statement of effects observed on each animal.

Summary of experimental feeding.

Horse.	Weight at beginning of experiment.	Final weight.	Gain (+) or loss (−) in weight.	Meal fed at beginning of experiment.	Meal fed at end of experiment.	Effects observed.
	Pounds.	*Pounds.*	*Pounds.*	*Pound.*	*Pounds.*	
Stanley	1,510	1,425	− 85	¼	2	Intermittent colic atttacks when fed large amounts of cottonseed meal.
Virginia	1,500	1,570	+ 70	.....	.....	
Maude	1,520	1,670	+150	¼	1¼	Refused ration containing over 1 pound of cottonseed meal.
Myrtle	1,475	1,475	.....	.....	.....	
Nell	1,443	1,485	+ 42	¼	1½	Died Sept. 25 from colic. Post-mortem examination showed malformation of small intestine. Death not attributed directly to feeding cottonseed meal.
Queen	1,295	1,410	+115	.....	.....	
Bertina	1,520	.....	.....	¼	.....	Died June 4, pneumonia. Death not attributed to feeding cottonseed meal.
Fauna	1,770	1,780	+ 10	.....	.....	
Pet	1,325	1,480	+155	¼	3	Died Sept. 8. Stomach and intestines highly inflamed from excessive feeding of cottonseed meal.
June	1,250	1,375	+125	¼	1½	No ill effects observed, although the mare would refuse to eat large quantities of the meal.
May	1,315	1,390	+ 75	.....	.....	
Castanette	1,260	1,440	+180	¼	3	No ill effects observed from feeding large quantity of meal.
Gladstone	965	950	− 15	¼	.....	Feeding cottonseed meal discontinued June 16, as he had acquired a dislike for it and constantly refused to eat a ration containing it.
Georgia	965	960	− 5	.....	.....	
Brown Bess	970	940	− 30	¼	2	No ill effects observed. The mare occasionally would leave a portion of the cottonseed meal.
Evarts	995	940	− 55	.....	.....	

CONCLUSIONS AND RECOMMENDATIONS.

Horses should be taught to eat cottonseed meal by giving them a very small quantity at first, about one-quarter of a pound a day, and increasing it very slowly, so that they gradually become accustomed to the taste and odor of the meal.

Cottonseed meal is a high protein feed and must be fed with care to horses and mules in order to avoid digestive disorders, to which work animals are subject.

When a horse shows dislike for the meal, the quantity fed should be reduced to the satisfaction of the individual.

Most horses show a dislike for the meal as soon as it becomes noticeable in their grain. Some individuals, however, relish the meal and can be fed larger amounts.

One pound a day per 1,000 pounds live weight is the most satisfactory quantity to feed. Although some animals will consume more with satisfactory results, it is not advisable to exceed this limit.

The most satisfactory method of feeding cottonseed meal to horses is by mixing it thoroughly with ground grains. This method, however, is not always practicable in the sections where cottonseed meal is most available.

Horses can easily separate cottonseed meal from whole oats or shelled corn if they form a dislike for the meal. This residue should not be left in the feed trough, as it ferments easily and has a disagreeable odor.

Mares which were fed cottonseed meal during the period of pregnancy did not show any ill effects from its consumption, nor were any ill effects noticeable on the colts when foaled. From observations in this experiment, cottonseed meal does not seem to prevent mares from becoming pregnant.

No apparently beneficial effects were observed on the coats of the horses receiving cottonseed meal. In some teams those receiving cottonseed meal had the better looking coats, while in other teams the horses not receiving the meal had the smoother and glossier coats.

The mares in this experiment thrived better and consumed their ration containing cottonseed meal more satisfactorily after they were turned out on grass. As cottonseed meal is not laxative in effect, there is a tendency for the feces to become hard and dry. The succulence supplied by pasture neutralizes this tendency and keeps the intestinal tract in better condition.

Feeding cottonseed meal in large quantities may result in serious digestive disorders, and even death in some instances. Post-mortem examination of one mare which died after receiving 3 pounds of cottonseed meal daily for 46 days disclosed an inflamed condition of the stomach and intestines. The indications in this case were that death was due to the effects of cottonseed meal on the system, and that the ill effects were not noticeable until too late to prevent the loss of the animal.

SUGGESTED RATIONS CONTAINING COTTONSEED MEAL.

The following daily rations have been prepared with a view of suggesting combinations of feed containing cottonseed meal, from which the feeder may derive rations that will meet his local needs. It should be noted that the following rations are for a horse weighing 1,000 pounds. Modifications of these rations should be made for heavier or lighter horses. For example, in order to meet the requirements for a horse weighing 1,250 pounds the rations suggested should be increased in accordance with the increase in weight, which in this case is 25 per cent. Roughly this would give the feed requirement for the heavier horse.

Daily rations for 1,000-pound horse, light work.

RATION No. 1.

½ pound cottonseed meal.
6 pounds oats.
14 pounds timothy hay.

RATION No. 2.

½ pound cottonseed meal.
7 pounds oats.
7 pounds oat straw.
7 pounds timothy hay.

RATION No. 3.

1 pound cottonseed meal.
6 pounds corn.
4 pounds cowpea hay.
10 pounds corn stover.

RATION No. 4.

1 pound cottonseed meal.
7 pounds corn-and-cob meal.
4 pounds cowpea hay.
10 pounds barley straw.

RATION No. 5.

1 pound cottonseed meal.
6 pounds corn.
14 pounds corn stover.

RATION No. 6.

1 pound cottonseed meal.
6 pounds corn.
6 pounds corn stover.
6 pounds sorghum fodder.

RATION No. 7.

1 pound cottonseed meal.
4 pounds rolled barley.
2 pounds wheat bran.
14 pounds barley straw.

RATION No. 8.

1 pound cottonseed meal.
6 pounds corn.
4 pounds millet hay.
8 pounds oat straw.

Daily rations for 1,000-pound horse, medium work.

RATION No. 1.

1 pound cottonseed meal.
9 pounds oats.
14 pounds timothy hay.

RATION No 2.

1 pound cottonseed meal.
2 pounds wheat bran.
8 pounds oats.
14 pounds oat straw.

RATION No. 3.

¾ pound cottonseed meal.
10 pounds corn.
4 pounds cowpea hay.
8 pounds corn stover.

RATION No. 4.

¾ pound cottonseed meal.
9 pounds corn.
4 pounds cowpea hay.
10 pounds sorghum fodder.

RATION No. 5.

1 pound cottonseed meal.
10 pounds corn-and-cob meal.
4 pounds cowpea hay.
10 pounds oat straw.

RATION No. 6.

1 pound cottonseed meal.
8 pounds rolled barley.
2 pounds wheat bran.
12 pounds barley straw.

RATION No. 7.

1 pound cottonseed meal.
2 pounds wheat bran.
8 pounds shelled corn.
6 pounds millet hay.
6 pounds oat straw.

RATION No. 8.

1 pound cottonseed meal.
3 pounds cane molasses (blackstrap).
7 pounds corn.
12 pounds crab-grass hay.

RATION No. 9.

¾ pound cottonseed meal.
9 pounds corn.
14 pounds mixed hay (timothy and clover).

Daily rations for 1,000-pound horse, heavy work.

RATION No. 1.

1 pound cottonseed meal.
12 pounds oats.
14 pounds mixed hay (timothy and clover).

RATION No. 2.

1 pound cottonseed meal.
2 pounds wheat bran.
12 pounds oats.
5 pounds alfalfa hay.
9 pounds oat straw.

RATION No. 3.

1 pound cottonseed meal.
2 pounds wheat bran.
10 pounds corn.
7 pounds cowpea hay.
7 pounds corn stover.

RATION No. 4.

1 pound cottonseed meal.
2 pounds gluten meal.
11 pounds rolled barley.
12 pounds timothy hay.

RATION No. 5.

1 pound cottonseed meal.
3 pounds peanut meal (ground with hull).
10 pounds corn-and-cob meal.
6 pounds cowpea hay.
8 pounds sorghum fodder.

RATION No. 6.

1 pound cottonseed meal.
2 pounds soy beans (ground).
11 pounds corn.
14 pounds corn stover.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO HORSE RAISING.

Available for Free Distribution by the Department.

Breeds of Draft Horses. (Farmers' Bulletin 619.)
Colts: Breaking and Training. (Farmers' Bulletin 667.)
How to Select a Sound Horse. (Farmers' Bulletin 779.)
Breeds of Light Horses. (Farmers' Bulletin 952.)
The Feeding of Horses. (Farmers' Bulletin 1030.)

HORSES SHOULD be taught to eat cottonseed meal by giving them a very small quantity at first, about one-quarter of a pound a day, and gradually increasing it as the animal becomes accustomed to the taste and odor of the meal.

Cottonseed meal must be fed with care to horses. If fed in large quantities it may result in serious digestive disorders and even death in some instances.

One pound of cottonseed meal per 1,000 pounds live weight is the safest and most satisfactory quantity to feed. Some horses will consume more with satisfactory results, but it is not advisable to exceed this limit.

To obtain best results, cottonseed meal should be fed by thoroughly mixing with ground grains. Only bright, high-grade meal should be used.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 930

Contribution from the Bureau of Plant Industry

WM A. TAYLOR, Chief

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THE PRODUCTION OF BINDER-TWINE FIBER IN THE PHILIPPINE ISLANDS.

By H. T. Edwards, *Specialist in Fiber-Plant Production, Office of Fiber-Plant Investigations.*

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SAFEGUARDING THE SUPPLY OF IMPORTED RAW MATERIALS.

IT IS ONLY within the last five years that any marked degree of attention has been given to the subject of safeguarding the supply of raw products imported into the United States. Apparently it has been assumed that the world production of such important staples as fiber, oil, and rubber would keep pace with the world demand, that there would be a free and relatively unrestricted exchange of these staples, and that there existed no danger of either an immediate or a future shortage of any of these materials.

There has existed, furthermore, a very limited and inadequate understanding of the complex situation that has arisen with the rapid development of modern manufacturing industries. There has been no general comprehension of the fact that there exists to-day a degree of interdependence between different and often widely separated industries that was almost unknown 50 years ago.

The World War brought an awakening with respect to these matters. With a decreased production of certain staple products, with

an increased demand for these same products, and with world transportation disorganized, it was made apparent that conditions might easily arise at any time which would seriously cripple a number of the basic and essential American industries. It was shown that the farmer is now dependent on the manufacturer and that the manufacturer is equally dependent in many instances on supplies of raw material imported from foreign countries over which the United States has absolutely no control. It was demonstrated beyond question that action should be taken in this country, wherever such action may be possible, to safeguard our future supply of the raw materials that are essential to the normal operation of our leading agricultural and manufacturing industries.

THE BINDER-TWINE FIBER SITUATION.

An illustration of the weakness of our industrial situation with respect to imported raw products is furnished by the conditions existing in the binder-twine industry.

With an annual production of approximately 2½ billions of bushels of grain crops that are largely harvested by machinery, the American farmers require each year about 200 million pounds of binder twine. Without this twine the machines can not be operated, the crops harvested, and the food supply of the country maintained.

With the exception of very limited quantities, the entire supply of binder twine used in the United States is manufactured from henequen and sisal fibers, and more than 90 per cent of the total supply of these fibers imported into the United States is received from Mexico. Henequen production in Mexico is confined largely to the one relatively small State of Yucatan (fig. 1). It is apparent, therefore, that any condition in Yucatan that might result in a material decrease in the output of henequen or any condition of world affairs that might result in the supply of Yucatan fiber being diverted to markets other than those of the United States would seriously affect the production of the most important staple food crops of this country.

The locations of political disturbances and of military operations during the last six years have not been such as largely to reduce the production or seriously to interfere with the distribution of Yucatan henequen. American manufacturers have been able to obtain the required supply of this fiber, although at prices representing an increase of approximately $28,000,000 in the yearly binder-twine bill of the American farmer. There is no assurance, however, that disturbances of the future or that increasing industrial competition under peace conditions may not affect both the production and the distribution of this essential product.

In order that the farmers of the United States may have reasonable assurance of being able to obtain at all times and under all conditions an adequate supply of binder twine at reasonable prices, it is necessary that an increased supply of binder-twine fiber be produced in United States territory or in countries over which the United States exercises political control. In view of this situation, investigations have been made by the United States Department of Agriculture for the purpose of determining in what places the natural conditions are most favorable for the production of sisal and henequen. As a result of these investigations, cooperative work has

FIG. 1.—Well-developed 9-year-old plants of henequen in Yucatan from which the sixth semiannual crop is being harvested.

been carried on during the last three years with the Philippine Bureau of Agriculture to encourage the increased production of binder-twine fiber in the Philippine Islands.

THE PHILIPPINE ISLANDS AS A SOURCE OF BINDER-TWINE FIBER.

With climatic and soil conditions favorable for the production of sisal, with large areas of unoccupied Government land, with a fairly abundant supply of relatively cheap labor, with good roads and cheap interisland water transportation, and with sisal plants already widely distributed in a number of different Provinces, the Philippine Islands possess the requirements essential for the development of a flourishing sisal industry.

At the time of the American occupation of the Philippines these islands were exporting each year a few hundred bales of so-called "Manila maguey" fiber. The maguey is a plant closely related to the true sisal and to Yucatan henequen, but it produces a fiber somewhat softer and finer than either sisal or henequen. It is probable that maguey (fig. 2) was originally introduced into the Philippine Islands from Mexico.

FIG. 2.—A maguey plant at the Lamao Experiment Station, Bataan Province, Philippine Islands.

In 1904 the Philippine Bureau of Agriculture organized a campaign to encourage the increased production of maguey and also imported sisal plants from the Hawaiian Islands. This work has been continued up to the present time, with the result that the exports of maguey fiber from the Philippine Islands increased from 875 tons in 1901 to 15,639 tons in 1916. The work of the Philippine Bureau of Agriculture brought about a large increase in the production of

maguey fiber in the Philippines, but it did not result in any material increase in the production of sisal fiber or in the production of machine-cleaned fiber, which is required for the manufacture of binder twine.

PRESENT CONDITION OF THE MAGUEY INDUSTRY IN THE PHILIPPINE ISLANDS.

Maguey and sisal are now grown in nearly every Province of the Philippine Islands. The production of fiber on a commercial scale is confined, however, to northwestern Luzon, where it is grown in the Provinces of Ilocos Norte, Ilocos Sur, and La Union, and to that part of the Visayan Islands which includes the islands of Cebu, Bohol, Siquijor, and a number of small islands near Cebu and Bohol. There are other islands and Provinces where conditions are favorable for the cultivation of maguey and sisal, and it is probable that, with the more general use of fiber-cleaning machines in the Philippines, there will be a gradual extension of the fiber industry into new districts.

The Ilocos Provinces of Luzon formerly produced the greater part of the maguey fiber exported from the Philippines, but there has been a rapid growth of the industry in the southern islands during recent years, with the result that this region now produces considerably more fiber than the Luzon Provinces. During the month of May, 1920, the production of maguey and sisal fibers in the Visayas was 8,801 bales, as compared with 4,482 bales produced in the Ilocano Provinces. While there is opportunity for further development of this industry in northern Luzon, the conditions are more favorable in the southern islands.

Table I shows the areas of maguey and sisal plants under cultivation in the Philippine Islands for the last eight years, as reported by the division of farm statistics of the Philippine Bureau of Agriculture.

TABLE I.—*Area devoted to the cultivation of maguey and sisal crops in the Philippine Islands for the 8-year period from 1912 to 1919, inclusive.*

Year.	Area.	Year.	Area.
	Hectares.[1]		*Hectares.*[1]
1912	8,598	1916	30,804
1913	9,283	1917	28,099
1914	18,218	1918	32,601
1915	19,218	1919	28,455

[1] A hectare is euivalent to 2.471 acres.

While these figures may represent with a reasonable degree of accuracy the areas of maguey and sisal that were actually harvested during the years mentioned, it is believed that there was an increase in 1919, rather than a decrease, in the total area planted to these crops.

During the latter part of 1917 the use of salt-water retted maguey for the manufacture of binder twine was discontinued by American manufacturers, and there has been but little demand for this product in the American markets for the last three years. As a result, the exports of maguey fiber from the Philippines during 1918 and 1919 were less than during 1916 and 1917. There has not been a corresponding decrease, however, in the area under cultivation. In a few isolated cases maguey plants have been destroyed and the fields planted to other crops, but this limited decrease in area has been more than offset by new plantings.

Table II shows the production of maguey and sisal fibers in the Philippine Islands for the last eight years, as reported by the division of farm statistics of the Philippine Bureau of Agriculture.

TABLE II.—*Total and average production of maguey and sisal fibers in the Philippine Islands for the 8-year period from 1912 to 1919, inclusive.*

Year.	Production of fiber.	Average production per hectare.	Year.	Production of fiber.	Average production per hectare.
	Metric tons.	*Piculs.*[1]		*Metric tons.*	*Piculs.*[1]
1912..	4,628	8.51	1916....	13,389	8.98
1913..	3,619	6.17	1917....	17,190	12.31
1914..	7,583	11.65	1918....	16,664	11.99
1915..	6,315	8.05	1919....	12,318	10.83

[1] A picul is equivalent to 137.5 pounds.

When the use of Philippine salt-water retted fiber for the manufacture of binder twine was discontinued in 1917 it was, for the time being, a severe blow to the maguey industry. Fortunately for the maguey planters, there was a strong demand for this fiber in countries other than the United States, which partially offset the loss of the American market. As the action taken by American manufacturers in regard to salt-water retted fiber has served to stimulate the interest of the planters in machine cleaning, this temporary loss of the American market may serve to promote, rather than to retard, the development of this industry.

There has been an increased production of maguey fiber during recent months, and the present indications are that there will be a larger output of binder-twine fiber in the Philippines in 1920 than during any previous year. Table III shows the relative production of maguey and sisal in the Philippine Islands during the first five months of 1920, as compared with the production during the same periods in 1918 and 1919.

The production of maguey in the Philippine Islands with few exceptions is a small-plantation industry. Throughout the Provinces where maguey is grown there are many small fields and even smaller patches of maguey and sisal. The owners of these small plantings

have become accustomed to methods and practices that differ materially from the methods used on the large and well-equipped sisal and henequen plantations of other countries.

TABLE III.—*Comparative production of maguey and sisal fibers in the Philippine Islands for the months of January to May, inclusive, for the years 1918, 1919, and 1920.*

Month.	Comparative production (bales).		
	1918	1919	1920
January	8,834	9,154	10,717
February	7,753	5,554	13,319
March	10,860	6,875	16,312
April	9,063	6,664	13,227
May	9,235	9,595	13,337
Total	45,745	37,842	66,912

In the planting of maguey the land, usually rough and rocky, is cleared or partially cleared of shrubs and weeds, and the maguey plants, usually small and of inferior quality, are set out more or less irregularly (fig. 3). The distance between the plants is ordinarily not more than 3 or 4 feet and frequently even less. The plantings are then entirely neglected or are kept partially cleared until such time as the maguey plants are ready for the first cutting of leaves. On account of the close planting and the lack of cultivation the maguey fields frequently become an impenetrable jungle. The first cutting of leaves is usually made before any of the leaves are mature, and at both the first and the subsequent cuttings the plants are denuded of all but a small bunch of leaves. As a result of this overcutting many immature leaves are harvested and the development of the plants is retarded.

When the prices of fiber are low the maguey plantings are neglected and occasionally destroyed. When prices are high all available leaves are harvested regardless of whether or not they are ready for cutting. Harvesting is carried on irregularly and at the convenience of the owner. After being cut from the plant, the leaves are split in narrow strips and these strips are made into small bundles. The bundles of split leaves are then taken to the nearest sea beach or to the mouth of some tidal creek and are immersed in salt water for a period of one to two weeks. When the pulpy portion of the leaves has softened and retted sufficiently the bundles are removed from the water, and, in small quantities, the retted leaves are scraped, beaten on stones, and washed in salt water until all of the pulp is removed. The cleaned fiber is then dried in the sun. With these crude and wasteful methods the Philippine Islands during the calendar year 1916 produced 125,484 bales of maguey fiber, which was approxi-

mately 7.2 per cent of the total production of Yucatan for the same year. During the first five months of the calendar year 1920 the Philippine Islands produced 66,912 bales of maguey fiber, which was approximately 20 per cent of the production of Yucatan sisal for the same period.

The production of binder-twine fiber in all countries other than the Philippine Islands is conducted as a large-plantation industry. This is primarily due to the fact that the economical production of a good quality of binder-twine fiber involves the use of expensive fiber-cleaning machinery. The economical operation of this machinery requires a large and dependable supply of leaves, such as is ordinarily

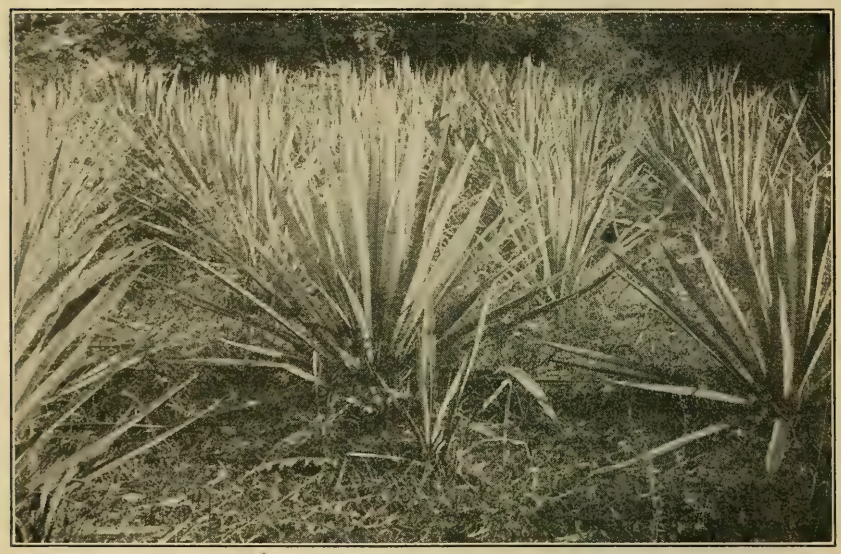

FIG. 3.—A maguey field at San Miguel, Ilocos Norte Province, Philippine Islands.

obtainable under conditions found in tropical countries only on large and well-organized plantations.

One of the fundamental problems, therefore, in encouraging the increased production of maguey and sisal fibers in the Philippine Islands is to increase the number of large plantations.

IMPROVEMENTS NEEDED IN THE MAGUEY INDUSTRY.

The reforms most urgently needed on the Philippine maguey plantations are better preparation of the land that is used for field planting, the establishment of nurseries, the use of larger and more vigorous sucker plants, wider spacing between the rows and between the plants in the row, improved cultivation, and a radical change in the methods of harvesting the leaves and cleaning the fiber.

It is possible that the introduction of cleaning machines will do more to improve conditions on the maguey plantations than any other work that can be done. The planters who are investing their capital in large modern machines will naturally be interested in their profitable operation. In order to operate them profitably a large and regular supply of good leaves is essential. The quality of leaves required for the most successful operation of the machines can not be produced without the introduction of improvements in methods of production. This fact has already been demonstrated where Government machines have been operated, and it will be more generally and more clearly understood now that machines are being purchased and operated by the planters themselves.

PURPOSE OF THE COOPERATIVE WORK WITH THE PHILIPPINE BUREAU OF AGRICULTURE.

During the calendar year 1916 it was proposed that the United States Department of Agriculture and the Philippine Bureau of Agriculture engage in cooperative work to encourage the increased production of binder-twine fiber in the Philippine Islands.

The plan of this proposed cooperation, which was subsequently approved, was based on the following essential considerations:

(1) That binder twine is now an article indispensable to practically all American grain growers.

(2) That more than 80 per cent of the binder twine now manufactured in the United States is made from henequen (Yucatan sisal).

(3) That the dependence of the American farmers and manufacturers on this one source of supply of binder-twine fiber is a serious danger to American agriculture.

(4) That it is extremely desirable that binder-twine fiber be produced in increasing quantities in territory under the control of the United States.

(5) That there are in the Philippine Islands extensive areas having conditions of climate and soil suitable for the production of maguey and sisal and these plants are already widely distributed in the Philippines.

(6) That the production of binder-twine fiber in the Philippine Islands can be increased by the use of modern methods such as have made the industry profitable elsewhere.

(7) That without the use of adequate machinery for extracting the fiber the industry can not be profitably and extensively developed.

(8) That the most important activities of this cooperative work should be the purchase, installation, and operation for demonstration purposes of fiber-cleaning machines of types regarded as best adapted to the needs and conditions in the Philippines and the distribution to the growers of approved types of plants.

(9) That the expenses, estimated at $40,000 per annum, be borne jointly by the Government of the United States and the Government of the Philippine Islands.

(10) That this cooperative work should ultimately result to the advantage of the United States by increasing the production of binder-twine fiber in the Phil-

ippine Islands to such an extent as to prevent a monopoly of this product by any one country and to the advantage of the Philippine Islands by building up an important industry in the poorest and most thickly populated Provinces.

OUTLINE OF THE COOPERATIVE WORK.

Under the terms of this cooperative agreement the Philippine Bureau of Agriculture has purchased and operated for demonstration purposes one Prieto No. 51 fiber-cleaning machine and one Prieto No. 251 fiber-cleaning machine, and has installed and operated one Prieto No. 251 fiber-cleaning machine purchased by the United States Department of Agriculture; has distributed sisal bulbils purchased by the United States Department of Agriculture in the Hawaiian Islands and sisal and maguey bulbils and suckers grown at La Carlota Experiment Station; has detailed one or more employees on extension work in the Provinces; and has conducted educational and publicity work.

The United States Department of Agriculture furnished one Prieto No. 251 fiber-cleaning machine and 500,000 sisal bulbils purchased in the Hawaiian Islands, and detailed one specialist on this work in the Philippine Islands from August, 1917, to June, 1918, and from December, 1919, to April, 1920.

When the cooperative Government work was first organized, a committee representing the United States Department of Agriculture, the Philippine Government, and the commercial fiber interests in the Philippine Islands was appointed by the Governor General of the Philippine Islands to investigate the maguey industry and to make recommendations as to the means that should be employed to encourage the increased production of binder-twine fiber in the Philippine Islands. Subsequent Government work has been based on the recommendations of this committee.

During the season of 1917–18 an educational campaign was carried on throughout the Philippine Islands for the purpose of disseminating information regarding the binder-twine fiber situation and the possibilities for increasing the production of maguey and sisal fibers in the Philippines. Field agents of the Philippine Bureau of Agriculture were detailed in the Provinces where maguey is grown to carry on extension work in the interests of the industry. Two fiber-cleaning machines were received in Manila during the latter part of 1917. These machines were first installed and tested in Manila and subsequently were installed and operated for demonstration purposes elsewhere—one in the Province of Cebu and the other in the Province of Ilocos Sur. Sisal bulbils to the number of 250,000 were imported from the Hawaiian Islands and distributed to the agricultural schools and to the maguey planters. The Government regulations providing for the classification and grading of fibers were so amended as to pro-

vide necessary grades for machine-cleaned maguey and sisal, and plans were prepared for a Government sisal plantation.

During the season of 1919–20 all of the maguey-producing Provinces were visited for the purpose of ascertaining the degree of progress that had been made and the changes or improvements that should now be made. Conferences were held with the local Government officials and the planters for a discussion of the fiber situation. All of the fiber-cleaning machines that have been installed were inspected and necessary arrangements were made for remedying any defects in the operation of these machines. Arrangements were completed for the transfer of the Government fiber-cleaning machine now located at San Fernando, Cebu; to the island of Siquijor, where the need for a demonstration of the machine is particularly urgent. Numerous tests were made with the fiber-cleaning machines that are now in operation to ascertain the capacity of these machines when operated under normal Philippine field conditions and to determine the relative results obtained with sisal and maguey fibers. Sisal bulbils were received from the Hawaiian Islands, and 250,000 distributed in the Provinces. Diseased sisal plants were located in the Province of Cebu, and arrangements were made for the destruction of these plants. A demonstration sisal nursery was planted at the Singalong Experiment Station in Manila. Plants were furnished and arrangements made for the establishment of a demonstration sisal nursery and field plantings at the College of Agriculture at Los Banos and for a course of instruction to be given at the College of Agriculture covering the more essential features of the sisal industry. A special effort was made to disseminate as widely as possible accurate information regarding the possibilities for the future development of the binder-twine fiber industry in the Philippine Islands, with a view to stimulating its continued growth.

RESULTS OF THE COOPERATIVE WORK.

THE MACHINE SITUATION.

It was considered when the cooperative work was started in 1917 that the one thing most urgently needed in order to establish the production of binder-twine fiber in the Philippine Islands on a permanently stable and profitable basis was the introduction of machine cleaning. The cleaning of maguey and sisal by retting the leaves in salt water is a slow, tedious, and wasteful process which requires much cheap labor and produces in the end a fiber of inferior quality. The retting system encourages, furthermore, the continued use of unsatisfactory methods on the plantations, as the small and immature leaves are more easily retted than the large mature leaves. With salt-water retting the only available means of cleaning maguey, the

cultivation of this crop was restricted to limited areas of land near the seacoast, as the leaves can not profitably be transported for long distances. It was clearly evident that the producers of retted maguey and sisal fibers could not hope to compete successfully with the producers of machine-cleaned sisal in other countries. If any further argument in favor of machine cleaning was necessary, it was furnished during the latter part of 1917, when American manufacturers decided to discontinue the use of salt-water retted fiber for binder twine. As the principal use of maguey had been for the manufacture of binder twine, the results of this action would have been disastrous to the maguey industry had there not been at the time an unusually strong demand for this fiber for other purposes and in countries other than the United States. There is no probability, however, that there will ever be, under normal industrial conditions, a steady demand for retted maguey and sisal fibers at prices that will make the production of these fibers a profitable industry.

In 1917 no fiber-cleaning machines for maguey and sisal were in operation in the Philippines and no commercial agencies for such machines had been established in the Islands. The planters were not familiar with the work of machines of this character and did not know where or under what conditions machines could be obtained.

One of the first lines of cooperative work undertaken was to demonstrate that maguey and sisal can be successfully and profitably cleaned in the Philippine Islands by the use of machinery. The Government has purchased, installed, and operated in the maguey-producing Provinces of the Philippines three modern fiber-cleaning machines. On account of the high cost of machinery and the lack of adequate transportation, this work has been conducted under unusually difficult conditions. It has, however, produced definite and positive results. The maguey planters have been shown that the use of machines for cleaning maguey and sisal in the Philippine Islands is entirely practicable, and a commercial agency for handling fiber-cleaning machines has been established in Manila, through which the Philippine planters are now able to purchase machines on very liberal terms.

On April 1, 1920, 18 modern fiber-cleaning machines were either in operation, were being installed, or had been ordered for use in the Philippine Islands. These 18 machines will have a total daily cleaning capacity of approximately 2,000,000 leaves. With an average yield of 50 pounds of fiber per 1,000 leaves, which is ordinarily obtained with henequen and sisal, the total daily output from 2,000,000 leaves would be 50 tons of fiber, or the total annual output, for 300 working days, would be 15,000 tons of fiber, which is more than the present total production of maguey and sisal in the Philippine Islands. With the small maguey leaves that are now obtainable in

the Philippines, from 8,000 to 10,000 leaves are required to produce 1 picul (137.5 pounds) of fiber. Two million leaves of this character would produce 15 tons of fiber, or with a daily supply of 2,000,000 leaves an annual output of 4,500 tons of fiber. The machine situation in the Philippine Islands may be summarized by the statement that a sufficient number of modern fiber-cleaning machines to clean from one-third to one-half of the present total output of maguey and sisal fiber have already been installed or have been ordered by the planters. It is not unreasonable to assume that this situation is largely the direct result of the cooperative work organized and carried on by the Government.

An important problem in connection with the machine work has been that of determining the type of machine best adapted to existing Philippine conditions.

With respect to size and cleaning capacity, three standard types of fiber-cleaning machines are now manufactured in the United States. These types are represented by the small machine, which cleans 3,000 leaves per hour; the medium-sized machine, which cleans 5,000 leaves per hour; and the large machine, which cleans 15,000 leaves per hour. The manufacturers ordinarily recommend the purchase of the larger machines, as it is claimed that they are more easily, satisfactorily, and economically operated.

The Philippine planters, before the Government demonstrations with machines were made, were urgent in their demand for small machines. The arguments presented in favor of the small machines were that practically all the maguey plantations were too small to furnish the number of leaves required for the operation of a large machine and that but few of the planters had sufficient capital to purchase such a machine.

When the three Government machines were obtained it was considered advisable to purchase one machine of the smallest size and two of medium size. It was desired to ascertain whether the small machines could be profitably operated under Philippine conditions, and it was believed that the largest machines would be found too large to meet the requirements of the Philippine planters. These three machines have been operated intermittently for a period of two years with the following results:

With the small maguey leaves, which constitute practically the entire leaf supply now available in the more important fiber-producing Provinces, the capacity of the small machine is not sufficient to make its operation profitable. With sisal or with large maguey leaves it appears that this size can be operated with a small margin of profit.

The factor of small leaves and consequent lessened cleaning capacity is not as serious a matter with the medium-sized machine as it with the small one. With good business management and an adequate supply of leaves it should be possible to operate this machine profitably under existing Philippine conditions.

Although the large machines have not yet been tested in the Philippines, the indications are that in locations where a large supply of leaves is obtainable these will prove to be most satisfactory.

Having observed the Government demonstrations that have been made with machines, most of the Philippine planters now prefer the largest machines that can be obtained. This is shown by the fact that during the last year orders have been placed for 11 of the large machines and 1 of medium size. None of the small machines have been purchased during this period.

A number of tests have been made with the Government machines for the purpose of determining their capacity, the yield of fiber obtained from a given number of leaves, the relative yields of maguey and sisal, the relative quality of fiber obtained from maguey and sisal, and the relative percentage of fiber obtained by machine cleaning and retting. As these machines were adjusted for cleaning maguey rather than sisal, as the men who operated the machines were not accustomed to handling the large sisal leaves, and as sisal leaves of satisfactory quality were not obtainable, the results of these tests so far as sisal is concerned can not be considered as conclusive.

It was found that the medium-sized machine, the cleaning capacity of which was supposed to be 5,000 leaves per hour, will, under average conditions, clean about 7,000 of the small maguey leaves per hour. In one test made with 1,000 leaves, cleaning was done at the rate of 10,909 leaves per hour. The best result obtained with sisal was 4,615 leaves per hour.

The yield of fiber obtained from the average-sized maguey leaves was about 17 pounds per 1,000 leaves, or approximately one-third of that ordinarily obtained from henequen and sisal. The largest yield from maguey in any of the tests was 26 pounds of fiber per 1,000 leaves. While these leaves were considerably larger than the average of the maguey leaves that are now being cleaned, they were much smaller than the maguey leaves that can be produced on plants which are properly planted and cared for. The largest yield of sisal obtained in these tests was 47.74 pounds of fiber per 1,000 leaves, while other tests gave considerably smaller yields. As it was impracticable to obtain sisal leaves of satisfactory size and quality, these tests should not be considered as an indication that Philippine sisal produces less fiber than the sisal of other countries.

With the quality of maguey leaves now obtainable and with favorable operating conditions, the medium-sized machine should clean approximately 1,500 pounds of maguey fiber in an 8-hour day. In all the tests the weight of sisal fiber cleaned in a given period of time was less than that of maguey fiber cleaned in the same period.

Two tests indicate that the machines clean sisal more satisfactorily than maguey. The results obtained in these tests were as follows:

Maguey.—10 per cent grade A, 75 per cent grade B, 15 per cent grade C.
Sisal.—85 per cent grade A, 15 per cent grade B.

The tests made to determine the relative percentage of fiber obtained by machine cleaning and retting indicated that with both maguey and sisal the retting process gives a slightly larger percentage of fiber than is obtained with machine cleaning.

The essential conclusion that can be drawn from the results of these tests is that, with good business management and an adequate supply of leaves, the medium-sized and probably the large fiber-cleaning machines can be profitably operated in the Philippine Islands and can be used for cleaning either maguey or sisal.

THE SISAL SITUATION.

A detailed and accurate statement showing the relative value of sisal and maguey when grown under Philippine conditions can not be made at the present time. It would not be possible to find in any one locality in the Philippine Islands even 1 acre each of properly cultivated maguey and sisal from which complete and reliable data could be obtained. No accurate data are obtainable showing the production of leaves and fiber for a given area of either sisal or maguey in the Philippine Islands. It appears, however, that sisal will prove to be a more profitable crop than maguey in the Philippines. This assumption is based on the known production of sisal in other countries and the estimated production of maguey in the Philippines, as well as on the fact that sisal leaves are more easily and satisfactorily cleaned by the machines than maguey leaves and that sisal fiber is more satisfactory than maguey fiber for binder-twine purposes. (Fig. 4.)

During the last year it has been ascertained that maguey leaves can be satisfactorily cleaned by the machines without being crushed before cleaning, and the tests indicate that a given weight of maguey leaves will produce a larger percentage of dry fiber than the same weight of sisal leaves. These facts, while having an important bearing on the subject of the relative value of sisal and maguey, may be taken to indicate that maguey can be profitably grown where sisal is not readily obtainable, rather than the conclusion that maguey is a more profitable crop than sisal.

For a number of years the Philippine Bureau of Agriculture has been importing sisal plants from the Hawaiian Islands, and during the last two years the United States Department of Agriculture has purchased 500,000 sisal bulbils for distribution in the Philippines.

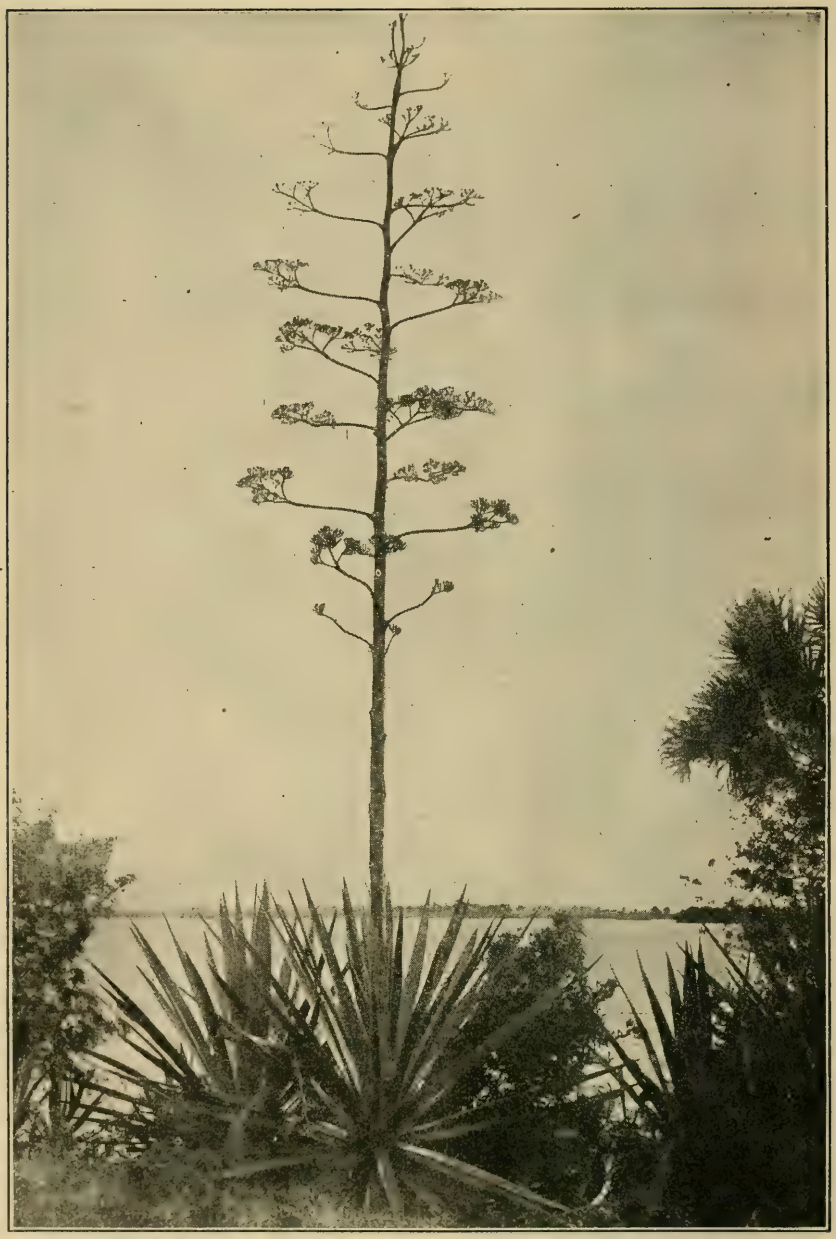

FIG. 4.—Sisal in Florida. The more important sisal plantings throughout the world have originated from plants grown in Florida, although that State has never produced sisal fiber in commercial quantities.

The shipment of 250,000 sisal bulbils received in Manila in 1918 was distributed by the Philippine Bureau of Agriculture to planters and to agricultural schools in the Provinces. Arrangements had been made for placing these plants in Government nurseries, but lack of

funds made it impossible to establish them. It was believed that it would be advisable to have a number of small demonstration plantings in connection with the school gardens at various places in the maguey-producing Provinces. The results obtained with the school-garden nurseries were not satisfactory, and future distributions will be made direct to the planters.

In March, 1920, a second shipment of 250,000 sisal bulbils was received in Manila. As fiber-cleaning machines are now being installed at different places both in the Ilocos Provinces and in Cebu, and as the machines do more satisfactory work with sisal than with maguey, it was considered advisable to limit the distribution of these plants to a small number of responsible planters whose plantations are located near the places where machines are to be installed. Some of these plants were used for demonstration nurseries at the Singalong Experiment Station in Manila and at the College of Agriculture in Los Banos.

While the establishment of sisal in the Philippines has been slow, the distribution of Hawaiian plants has been by no means without results of value. From the Government nurseries at La Carlota, in the Province of Occidental Negros, large numbers of sisal bulbils and suckers have been distributed. A sisal industry has been established on the island of Siquijor, which is now the principal industry of that island, and it is probable that the Siquijor industry alone would justify all expenditures that have been made by the Government in this work.

The introduction of cleaning machines in the Philippines will probably result in a decided change in the attitude of the planters toward sisal, and in the localities where machines are installed it should be possible to get sisal nurseries established. Wherever a machine has been operated the planters have had an opportunity to see that sisal is cleaned more easily and produces a better quality of fiber than maguey.

The principal source of supply of sisal plants in the Philippine Islands is the island of Siquijor. While the Siquijor plantings are quite widely scattered and accurate data showing the total area are not available, there are several hundred acres of sisal on that island. On Cebu there is a sisal plantation in the municipality of Borbon, in the northern part of the island. In 1916 the Philippine Bureau of Agriculture obtained 100,000 sisal bulbils from this plantation, and both suckers and bulbils are available at Borbon at the present time. There are a number of smaller plantings in different parts of Cebu, and throughout all of the maguey-producing Provinces there are small patches and scattering plants of sisal.

Unless the demand for sisal plants in the Philippine Islands becomes much greater than now appears probable, the plantations of Siquijor,

Cebu, and Bohol should furnish an abundant supply of suckers and bulbils for future use.

IMPROVEMENTS ON PLANTATIONS.

The field agents of the demonstration and extension division of the Philippine Bureau of Agriculture have been working with the maguey planters for a number of years with a view to encouraging the use of improved methods on the plantations. It has been extremely difficult to get satisfactory results in this work, as most of the producers of maguey have small plantings only and are not disposed to make any changes in the methods to which they are accustomed. With the introduction of cleaning machines and with the consequent increased demand for maguey and sisal leaves of good quality, there will be an opportunity for the employees of the Philippine Bureau of Agriculture to continue this work under much more favorable conditions than those which have existed in the past.

SUMMARY.

Important agricultural and manufacturing industries of the United States are now largely dependent on supplies of imported raw products. Necessary action should be taken to safeguard our future supply of these products.

The grain-producing industry of the United States can not be maintained without the use of harvesting machinery, and this machinery can not be operated without binder twine.

The greater portion of the binder twine used in the United States is manufactured from henequen and sisal fibers, and more than 90 per cent of the total supply of these fibers imported into the United States is received from Yucatan.

This dependence of our most important agricultural industry on one small State of a foreign country constitutes a grave menace to American agriculture.

In order to remedy this situation, it is essential that an increased supply of binder-twine fiber be produced within the territory of the United States or in countries over which the United States exercises political control.

The Philippine Islands possess the requirements necessary for the development of a flourishing sisal industry.

The production of binder-twine fiber in the Philippine Islands has been restricted in the past by reason of the antiquated methods that are in general use by the planters, and a number of reforms in this industry are urgently needed.

For the last three years the United States Department of Agriculture has been cooperating with the Philippine Bureau of Agriculture

for the purpose of encouraging the increased production of binder-twine fiber in the Philippine Islands.

The more important lines of work undertaken have been the introduction of machine cleaning to replace the unsatisfactory retting process, the distribution of sisal plants, and the introduction of improvements on the plantations.

As a result of this work, machine cleaning has been established on a commercial basis, and 12 large modern fiber-cleaning machines have been purchased by Philippine planters during the last 18 months; 500,000 sisal bulbils have been imported into the Philippine Islands from the Hawaiian Islands; and there is now enough sisal in the Philippines to furnish an abundant supply of plants for future use. While there has been no marked and widespread improvement of conditions on the plantations, there has been a fair degree of progress.

The production of maguey and sisal fibers in the Philippine Islands for the first five months of 1920 has been larger than during any similar period in previous years. During this period the production of Philippine maguey and sisal has been approximately 20 per cent of the henequen production of Yucatan.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 931

Contribution from the Bureau of Public Roads, THOS. H. MacDONALD, Chief, in cooperation with the Office of Farm Management and Farm Economics, H. C. TAYLOR, Chief.

Washington, D. C. ▼ February 25, 1921

CORN-BELT FARMERS' EXPERIENCE WITH MOTOR TRUCKS.

A study of 831 Reports from Farmers Who Own Motor Trucks.

By H. R. TOLLEY, *Agricultural Engineer*, and L. M. CHURCH, *Assistant in Farm Accounting.*

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SUMMARY.

This bulletin summarizes the experience with motor trucks of 831 grain and live-stock farmers in the corn belt who have motor trucks for use on their own farms.

The average size of their farms is 347 acres. This is considerably greater than the average size of all farms in the corn belt.

Only 14 per cent of these farms are less than 5 miles from market and 20 per cent of them are 15 miles or more. The average distance from market is 8 miles, while the average distance from market of all farms in the corn belt is probably not over 4 miles.

A little over one-fourth of these men have changed their markets, for at least a part of their produce, since purchasing trucks. For those who have changed market, the average distance to the old market was 7 miles and to the new market is 18 miles.

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Fifty-seven per cent of these men have not reduced the number of their work stock since purchasing trucks. Twenty-five per cent have disposed of one or two head, and 18 per cent of more than two head. The average reduction for all farms is 1.2 head. It is apparent, therefore, that to a large extent the motor truck supplements rather than supplants the horse on the farm.

The rated capacity of these trucks varies from one-half to 2 tons. Seventy-one per cent of them are rated at 1 ton, and only 9 per cent of them at less than 1 ton.

Experience with trucks has caused 57 per cent of these men to decide that the 1-ton size is best for their conditions; 25 per cent that the 1½-ton size is best; and 12 per cent that the 2-ton size is best. Practically one man in four has decided that a truck larger than the one he now owns is better suited to his conditions.

Ninety-one per cent believe that their trucks will prove to be profitable investments.

In the opinions of these men the principal advantage of a motor truck is in saving time, and the principal disadvantage is "poor roads."

As compared with horses and wagons, the trucks save about two-thirds of the time required for hauling to and from these farms.

On the average there are over eight weeks during the year when the roads are in such condition on account of mud, snow, ice, and frost that these trucks can not be used. The roads on which nearly 95 per cent of them usually travel are all or part dirt.

The condition of the roads prevented the use of the trucks with pneumatic tires a little less than seven weeks during the year covered by the reports, and of those with solid tires a little over nine weeks.

Twenty-four per cent of the trucks are equipped with pneumatic tires, 27 per cent with solid tires, and 49 per cent with pneumatics in front and solids in rear. However, experience has convinced 58 per cent that pneumatics are best for their conditions, 35 per cent that solids are best, and 7 per cent that pneumatics in front and solids in rear are best.

These men have return loads for their trucks about one-third of the time.

A majority of these men still use their horses for some hauling on the road.

On more than half of the farms all the hauling in the fields and around the buildings is still done with horses and wagons.

About 40 per cent of these men did some custom hauling with their trucks during the year covered by the reports. The average amount received by those who did such work was $132.

Their owners estimate that on the average these trucks travel 2,777 miles and are used on 112 days per year.

The average estimated life of these trucks is 6½ years, and on this basis depreciation is usually the largest single item of expense in connection with their operation.

The average cost of operation, including depreciation, interest on investment, repairs, registration and license fees, fuel, oil, and tires, is 15.2 cents per mile for the one-half and three-fourths ton trucks, 15.2 cents for the 1-ton, 21.3 cents for the 1¼ and 1½-ton, and 25.8 cents for the 2-ton.

The average cost of hauling crops, including the value of the driver's time at 50 cents per hour, is 24.0 cents per ton-mile with the one-half and three-fourths ton trucks, 24.1 cents with the 1-ton, 23.3 cents with the 1¼-ton and 1½-ton, and 21.5 cents with the 2-ton trucks.

Nearly 85 per cent of these trucks had not been out of commission when needed for a single day during the year covered by the reports, and 80 per cent of the owners stated that they had not lost any appreciable time on account of motor or tire trouble, breakage, or other mechanical difficulties when using their trucks. About one truck in 15 was out of commission more than five days, however, and one owner in 40 reported a loss of more than 5 per cent of the time when using his truck.

Half of these men own tractors as well as motor trucks. Most of the tractors are owned on the larger farms, however. Only 33 per cent of the men whose farms contain 160 crop acres or less own tractors, while 65 per cent of those with over 320 crop acres own them. The number of work stock kept on the farms where both trucks and tractors are owned is only slightly less than the number kept on the farms of corresponding size where only trucks are owned.

Seventy-eight per cent of these farmers state that their trucks reduce the expense for hired help. On those farms where there is a reduction the operators estimate that it amounts to $209 per year on the average.

METHOD OF STUDY.

In February and March of 1920 a questionnaire was sent to each of approximately 15,000 farmer truck-owners in Illinois, Indiana, Iowa, eastern Kansas, southern Minnesota, Missouri, eastern Nebraska, southeastern South Dakota, and southern Wisconsin. The questionnaire called for the type and size of farm, the use the farmer makes of his motor truck, the cost of operating it, his idea of its profitableness, the advantages and disadvantages of a truck for farm use, and other related information. In all about 15 per cent of the farmers replied to the questionnaire. However, only reports from grain and live-stock farmers, who raise corn as one of the principal crops, were included in the study.

All reports from men owning second-hand trucks or trucks made by the addition of truck units or attachments to passenger cars, those

from men who had owned their machines six months or less, and those from men who are using their trucks primarily for custom work or in connection with other business, and only incidentally for farm work were also excluded. Thus all of the 831 reports which form the basis of this bulletin are from men who are practicing the general grain and live-stock farming characteristic of the corn belt and who own trucks which were purchased new and which have been in use long enough to enable their owners to form an intelligent idea of their worth.

LOCATION AND SIZE OF FARMS.

The number of reports from the different States, the average size of the farms, and the average number of crop acres per farm are given in Table I. The average size of these farms where motor trucks are owned is considerably greater in every State than the average size of all farms. For instance, the reports of the 1910 census show that the average size of all farms in Illinois was only 129 acres, in Indiana 99 acres, in Iowa 156 acres, and in Missouri 125 acres. The number of acres planted to crops on the farms studied is also large, the average number of crop acres per farm being 248. Seventy-two per cent of the farms have over 160 crop acres and 21 per cent have more than 320 crop acres.

TABLE I.—*The number of reports from different States, average size of farm, and average number of crop acres per farm.*

State.	Number of reports.	Size of farm (acres).	Crop acres.	State.	Number of reports.	Size of farm (acres).	Crop acres.
Illinois	114	316	239	Southeastern South Dakota	154	471	301
Indiana	52	267	214	Southern Wisconsin	17	245	160
Iowa	216	285	230				
Eastern Kansas	44	466	274				
Southern Minnesota	32	286	228	Total	831	.....	.....
Missouri	86	381	260	Average	.....	347	248
Eastern Nebraska	116	324	233				

All the reports included from the States of Kansas, Nebraska, South Dakota, Minnesota, and Wisconsin are from men operating farms in the sections where corn is one of the principal crops. Every one of the 831 reports is from a man who raises corn as one of his principal crops, and in most cases the raising and feeding of hogs is an important enterprise. Reports from farms where dairying is the principal enterprise are not included.

DISTANCE TO MARKET.

Probably the most striking point concerning these farms is their great distance from market as compared with other farms in the same section of the country. Only 14 per cent of these farms are less than

5 miles from market and 20 per cent are 15 miles or more. A part of these men who have long hauls have changed their markets since buying trucks (see p. 19), but the average distance of all farms to the markets used before the purchase of trucks is 8 miles. (See fig. 1.)

Eight hundred and fourteen men reported the distance from their farms to the towns where the materials hauled by truck are usually

FIG. 1.—The motor truck is most advantageous to the man who is far from market or shipping point.

marketed. The exact number of farms at different distances from market is as follows:

117, or 14 per cent, are less than 5 miles from market.
325, or 40 per cent, are from 5 to 9 miles from market.
213, or 26 per cent, are from 10 to 14 miles from market.
75, or 9 per cent, are from 15 to 19 miles from market.
84, or 11 per cent, are 20 miles and over from market.

Farm survey records of other farms in different areas of the corn belt indicate that a majority of all the farms in this section are less than 5 miles from market. The average distance from market of 2,213 corn-belt farms, as shown by records in the office of Farm Management and Farm Economics, is 3.9 miles, and the number at different distances is as follows:

1,535, or 69.3 per cent, are less than 5 miles from market.
642, or 29.1 per cent, are from 5 to 9 miles from market.
36, or 1.6 per cent, are 10 miles and over from market.

These 2,200 farms can not be considered as exactly representative of all corn-belt farms, but a comparison of their distances from mar-

ket with the distances from market of the farms on which trucks are owned show clearly that most of the men whose reports form the basis for this bulletin have exceptionally long hauls.

SIZE OF TRUCKS.

The motor trucks owned on these 831 farms vary from one-half ton to 2 tons in size. Only 10 are of the one-half-ton size, however, and in all of the tables following the one-half-ton and three-fourths-ton sizes are combined into one group. Similarly, there are three trucks rated at 1¼ tons, and they have been combined with those rated at 1½ tons. None over 2 tons in size was reported. In general the larger trucks are used on the larger farms.

The number of the different sizes, the average size of the farms on which they are owned, and the average number of crop acres per farm are shown in Table II:

TABLE II.—*Number of trucks of different sizes and size of farms on which they are used.*

Size of truck.	Total number.	Average size of farm (total acres).	Average crop acres.
½-ton and ¾-ton	74	333	229
1-ton	588	328	236
1¼-ton and 1½-ton	109	407	294
2-ton	60	434	309
Total	831		
Average		347	248

AGE OF TRUCKS.

The length of time the 831 trucks had been in use at the time the reports were made is as follows:

394 had been in use 7 to 12 months.
375 had been in use 13 to 24 months.
55 had been in use 25 to 36 months.
7 had been in use 37 months or over.

ARE THESE TRUCKS PROFITABLE INVESTMENTS?

No attempt was made to determine to what extent the incomes of these men had been increased through the use of their trucks. However, 91 per cent of them stated that in their opinion their trucks will turn out to be profitable investments.

On the average these trucks travel 2,777 miles a year, and the cost of operation is between 16½ cents and 17 cents per mile, making the total annual cost from $460 to $470. Each truck displaces 1.2

head of work stock. At present the average cost of keeping a horse a year in the corn belt is around $200. The reduction in expense for this item, then, is in the neighborhood of $240 per farm. For all farms the average amount of hired help saved by the trucks is $163. On most farms these are the only two items of direct reduction in expense which can be credited to the truck, and on the average they amount to $60 or $70 less than the total cost of operating a truck.

To offset this added cost, custom hauling done with the trucks amounts to $50 per year for all farms, leaving only something like $10 or $20 annual net expense, which must be more than balanced by the saving of time of the owner and members of the family, the ability to get crops and live stock to market in better condition or at better times, and other benefits which are not directly measurable in dollars and cents, if the average truck is to be a profitable investment.

So far as could be determined, the size of the truck, the length of time it had been in use, and the size of the farm have little to do with the owner's idea of its profitableness. Some of the men who do not consider their trucks profitable have found them unreliable, so that the repair bills have been excessive or the machines have been out of commission when needed. Of all the 831 trucks only 19 had been out of commission when needed more than 10 days during the year covered by the reports, and the owners of 8 of these 19 trucks consider that they are unprofitable.

Eight-ninths of these men whose trucks are not proving profitable have not found it possible to dispose of any of their horses. Part of them have also found that they do not have enough work for the truck to justify the investment in such an expensive piece of equipment. About one-quarter of them had driven their trucks less than 1,000 miles and used them on less than 30 days during the year.

THE BEST SIZE.

The fact that these men considered their motor trucks profitable investments does not mean, however, that they are all entirely satisfied with the particular machines which they own. It is very important that the truck should be of the proper size for the hauling which it is to do. Ordinarily both the first cost and the cost of operation of a small truck will be less than of a large one, but often the small truck will not carry as large loads as is desired, and more trips to haul a given amount of material will therefore be necessary than with a larger truck. A truck which is too large, however, would have to be operated with only a partial load a great part of the time, and the extra cost may more than offset the advantage of being able to carry larger loads on exceptional occasions. Each farmer was

asked to state what size he considered the best for his conditions, regardless of the size he now owns, and 804 men answered as follows:

Of 70 who now own ½-ton and ¾-ton trucks—
- 2 consider that the best size is ½-ton.
- 29 consider that the best size is ¾-ton.
- 28 consider that the best size is 1-ton.
- 8 consider that the best size is 1½-ton.
- 3 consider that the best size is 2-ton.

Of 570 who now own 1-ton trucks—
- 1 considers that the best size is ¾-ton.
- 423 consider that the best size is 1-ton.
- 2 consider that the best size is 1¼-ton.
- 100 consider that the best size is 1½-ton.
- 42 consider that the best size is 2-ton.
- 2 consider that the best size is over 2-ton.

Of 107 who now own 1¼-ton and 1½-ton trucks—
- 7 consider that the best size is 1-ton.
- 2 consider that the best size is 1¼-ton.
- 85 consider that the best size is 1½-ton.
- 11 consider that the best size is 2-ton.
- 2 consider that the best size is over 2-ton.

Of 57 who now own 2-ton trucks—
- 3 consider that the best size is 1-ton.
- 10 consider that the best size is 1½-ton.
- 42 consider that the best size is 2-ton.
- 2 consider that the best size is over 2-ton.

In all—
- 2 consider that the best size is ½-ton.
- 30 consider that the best size is ¾-ton.
- 461 consider that the best size is 1-ton.
- 4 consider that the best size is 1¼-ton.
- 203 consider that the best size is 1½-ton.
- 98 consider that the best size is 2-ton.
- 6 consider that the best size is over 2-ton.

Nearly 95 per cent of the total prefer either the 1-ton, 1½-ton, or 2-ton size, with the 1-ton size preferred by 57 per cent of the total. Some of these men have evidently purchased trucks which experience has proved to be too small for their needs. While 583, over 72 per cent, consider that the size they now own is best for their conditions, 200, approximately 25 per cent, prefer sizes larger than they now own, and only 21, less than 3 per cent, prefer sizes smaller than they own.

ADVANTAGES AND DISADVANTAGES.

There are many advantages in the ownership of a motor truck, but just how great these advantages are and which ones should be given the greatest weight are questions which the man who has not had experience with a motor truck can seldom answer. A summary of the answers of 712 of these truck owners to the question "What

is the principal advantage of a motor truck for farm use?" is given in Table III:

TABLE III.—*The principal advantage of a motor truck as given by 712 farmers.*

Principal advantage.	Number reporting.	Per cent of total.	Principal advantage.	Number reporting.	Per cent of total.
Time saved	635	89	Better market	4	1
Save horses	32	4	Other	18	3
Convenience	17	2			
Reduce expense	6	1	Total	712	.....

Nearly 90 per cent of the owners report that the saving of time is the principal advantage. There are other advantages, of course, but in the minds of these farmers this is the principal one. While only four of these men report that the principal advantage of the truck is that it enables them to go to a better market, more than a fourth of the total number are going to better markets now than before the purchase of their trucks. Going to a market which is farther from the farm is simply a matter of taking more time for marketing, and a considerable number of the men who say that saving of time is the principal advantage find that the truck saves them sufficient time to enable them to go to the better market. Reducing shrinkage when marketing live stock, which is often mentioned as one of the big advantages of a motor truck, is also largely a matter of reducing the time required for getting the stock from farm to market.

The fact that such a small number consider the saving of horses, the reducing of expense, and added convenience, as the principal advantages of the truck, indicates that the amount of time which the motor truck will save, which may incidentally result in reaching a better market or getting live stock and crops to market in better condition, is the item which should be given paramount importance when considering the purchase of a motor truck.

The disadvantages of a truck should be considered as well as the advantages, and these men were asked what they had found to be the principal disadvantage. A summary of 413 answers to this question is given in Table IV. Of the remaining 418 farmers 261 did not answer the question, and 157 stated that they knew of no disadvantages in owning a truck.

TABLE IV.—*The principal disadvantage of a motor truck as given by 413 farmers.*

Principal disadvantage.	Number reporting.	Per cent of total.	Principal disadvantage.	Number reporting.	Per cent of total.
Poor roads	299	73	Incompetent driver	5	1
Cost of operation	46	11	Other	14	3
First cost	33	8			
Soft ground	10	2	Total	413	.....
Mechanical trouble	6	2			

It is seen that 73 per cent consider that "poor roads" is the principal disadvantage. A large percentage of the reports stated that there is some time during the year when the roads are in such a condition that motor trucks can not be used. (See p. 17.) The men who live on unimproved roads, of course, have the greatest handicap in this respect, but even the best of roads may be impassable for a truck because of snow at certain times of the year in this section. After poor roads the cost of the truck, either the cost of operation or the first cost, is considered the greatest disadvantage. The fact that the truck can not be operated satisfactorily on soft ground is next in importance, and troubles due to incompetent drivers and mechanical defects complete the list of disadvantages mentioned by more than one or two farmers.

ROAD HAULING WITH TRUCKS.

All of the material hauled to and from these farms has been divided into five general classes—viz, crops, live stock, building material, fuel, and other material. An idea of the relative amounts of these different materials hauled by the trucks can be obtained from the fact that, during the year covered by the reports—

481 farmers reported hauling a total of 40,029 tons of crops.
339 farmers reported hauling a total of 6,629 tons of live stock.
166 farmers reported hauling a total of 7,111 tons of building material, including fencing.
120 farmers reported hauling a total of 1,642 tons of fuel.
132 farmers reported hauling a total of 7,704 tons of other material.

All crops are included, but a large percentage of the total is grain. Similarly hauling all kinds of live stock was reported, but hogs make a large percentage of the total. (See fig. 2.)

Each farmer reported the weight of the load which he ordinarily hauls, the length of haul, and the time required for the round trip with the truck. Similar information was given for hauling with horses and wagons before the purchase of trucks. The time required for the round trip includes the time required for loading and unloading the truck or wagon.

Table V shows a comparison of the size of load, length of haul, and time required for hauling crops with trucks of different sizes, and with wagons before the purchase of trucks. Table VI gives a like comparison for live stock, Table VII for building material, and Table VIII for fuel.

The hours per ton-mile in each case are obtained by dividing the hours per round trip by the product of the size of the load in tons and the length of haul in miles. For instance, in Table I, a $\frac{1}{2}$-ton or $\frac{3}{4}$-ton truck hauling a load of 2,652 pounds a distance of 8.0 miles ac-

complishes 10.61 ton-miles of hauling. Since it takes 1.7 hours to make the round trip the time required per ton-mile is 0.16 hour.

A comparison of the hours per ton-mile required for hauling with truck with the hours per ton-mile for hauling with wagon gives the proportion of time saved by the truck. When hauling crops and building material the average size of load hauled with the ½-ton and ¾-ton and the 1-ton trucks is smaller in each case than the average size of load hauled with wagon. The reverse is true for the larger-sized trucks. When hauling fuel the loads hauled with all except the 2-ton trucks are smaller than the loads with wagons. On account of this the proportion of time saved by the larger trucks is somewhat greater than that saved by the smaller ones.

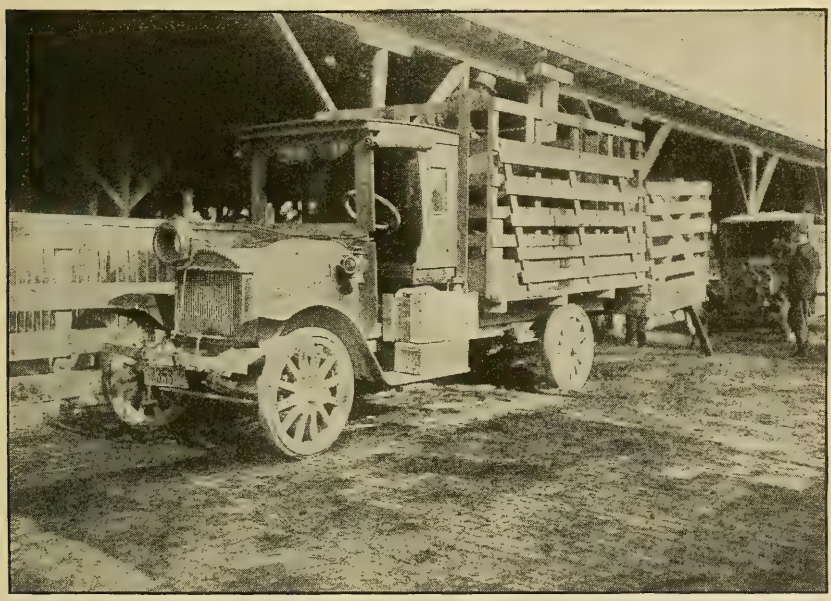

FIG. 2.—Unloading hogs at stockyards from farm-owned truck. Motor trucks enable many farmers to haul live stock direct to central markets which are too far away to be reached with horses and wagons.

TABLE V.—*Comparison of time required to haul crops with trucks and with wagons before the purchase of trucks (481 reports).*

Size of truck.	With truck.				With wagon.			
	Size of load (pounds).	Distance (miles—one way).	Hours per round trip.	Hours per ton-mile.	Size of load (pounds).	Distance (miles—one way).	Hours per round trip.	Hours per ton-mile.
½-ton and ¾-ton	2,652	8.0	1.7	0.16	2,892	7.1	5.4	0.53
1-ton	2,626	9.1	2.2	.18	2,937	8.8	6.4	.50
1¼-ton and 1½-ton	3,490	8.9	2.0	.13	3,098	8.9	6.3	.46
2-ton	4,409	9.4	2.3	.11	3,143	8.6	6.2	.46

TABLE VI.—*Comparison of time required to haul live stock with trucks and with wagons before the purchase of trucks (339 reports).*

Size of truck.	With truck.				With wagon.			
	Size of load (pounds).	Distance (miles—one way.)	Hours per round trip.	Hours per ton-mile.	Size of load (pounds).	Distance (miles—one way).	Hours per round trip.	Hours per ton-mile.
½-ton and ¾-ton	1,831	8.2	1.4	0.19	1,698	7.7	5.5	0.84
1-ton	2,023	12.1	2.7	.22	1,923	9.8	7.0	.74
1¼-ton and 1½-ton	2,512	11.6	2.4	.16	1,886	8.5	6.2	.77
2-ton	3,284	9.4	2.0	.13	1,947	8.5	6.0	.73

TABLE VII.—*Comparison of time required to haul building material with trucks and with wagons before the purchase of trucks (166 reports).*

Size of truck.	With truck.				With wagon.			
	Size of load (pounds).	Distance (miles—one way.)	Hours per round trip.	Hours per ton-mile.	Size of load (pounds).	Distance (miles—one way).	Hours per round trip.	Hours per ton-mile.
½-ton and ¾-ton	2,475	6.3	1.6	0.20	2,850	7.0	5.1	0.51
1-ton	2,548	8.6	2.2	.20	3,049	8.1	6.1	.49
1¼-ton and 1½-ton	3,813	7.6	2.0	.14	3,310	7.2	5.4	.45
2-ton	4,227	8.3	2.2	.13	3,245	7.5	6.6	.54

TABLE VIII.—*Comparison of time required to haul fuel with trucks, and with wagons before the purchase of trucks (120 reports).*

Size of truck.	With truck.				With wagon.			
	Size of load (pounds).	Distance (miles—one way.)	Hours per round trip.	Hours per ton-mile.	Size of load (pounds).	Distance (miles—one way).	Hours per round trip.	Hours per ton-mile.
½-ton and ¾-ton	2,533	7.4	1.8	0.19	2,808	7.9	6.3	0.57
1-ton	2,523	8.3	2.2	.21	2,815	7.8	6.1	.56
1¼-ton and 1½-ton	3,436	9.1	2.4	.15	3,464	8.3	6.5	.45
2-ton	4,917	9.2	2.2	.10	3,067	9.2	5.1	.36

TIME SAVED BY TRUCKS.

The length of time required to haul different distances with wagons and with trucks gives a more direct measure of the saving in time due to the use of a truck. Table IX shows the average time required to haul crops different distances with wagons as given by these men, and Table X the time required for hauling with motor trucks. The time required for hauling live stock and all other materials is practically the same as for hauling crops both with trucks and with wagons. For each distance it requires approximately one-third as long to make a round trip with a truck as it does with a wagon, and if the

same size loads are hauled with trucks as with wagons the time required per ton-mile will be practically one-third as much with truck as with wagon.

TABLE IX.—*Time required for hauling crops different distances with wagons.*

Distance hauled (miles).	Number of reports.	Hours per round trip.	
		Average.	Hours reported most frequently.
2 and 3	31	2.5	2½ (*10 reports*). 3 (*8 reports*).
4 and 5	89	3.7	3 (*19 reports*). 4 (*26 reports*).
6 and 7	133	4.7	4 (*31 reports*). 5 (*33 reports*).
8 and 9	94	6.1	5 (*26 reports*). 6 (*19 reports*).
10 and 11	72	7.5	6 (*17 reports*). 8 (*22 reports*).
12 and 13	51	9.0	8 (*9 reports*). 10 (*13 reports*).
14 and 15	22	8.9	9 (*6 reports*). 10 (*7 reports*).
16 and 17	12	10.8	.....
18 and 19	11	11.2	.....

TABLE X.—*Time required for hauling crops different distances with motor trucks.*

Distance hauled (miles).	Number of reports.	Hours per round trip.	
		Average.	Hours reported most frequently.
2 and 3	32	1.0	1 (*18 reports*).
4 and 5	89	1.2	1 (*33 reports*). 1¼ (*20 reports*).
6 and 7	142	1.6	1½ (*51 reports*). 2 (*35 reports*).
8 and 9	99	2.0	1½ (*14 reports*). 2 (*42 reports*).
10 and 11	82	2.4	2 (*26 reports*). 2½ (*21 reports*).
12 and 13	50	2.9	2½ (*13 reports*). 3 (*14 reports*).
14 and 15	28	2.9	3 (*13 reports*).
16 and 17	17	3.5	.....
18 and 19	17	4.1	.....

RETURN LOADS.

The percentage of time which a truck is run without load has a direct bearing upon the cost per unit of hauling with it. If an owner can arrange to haul a load to market and then bring back a load of supplies to his farm on the same trip he can reduce the time required and expense by practically 50 per cent. The reports of these men show that they have return loads for their trucks about 34 per cent of the time. About 10 per cent, however, stated that they never have return loads. Apparently the size of the truck, the length of the time it has been in use, and the distance from the farm to market have little to do with the number of return loads for the truck.

ROAD HAULING FOR WHICH TRUCKS ARE NOT USED.

The majority of these men still use horses to supplement their trucks in hauling on the road. Of 510 men who reported concerning their use of horses for road hauling only 195, or 38 per cent, stated that they do all their hauling with trucks. The reasons given by 305 of the remaining 315 for using horses for hauling on the road are shown in Table XI. It is seen that nearly three-fourths of these men give "poor roads" as the reason for using horses; that is, it was necessary to do some hauling to and from the farm at some time during the year when the roads were in such condition that the truck could not be used. After poor roads the reason given most frequently is that the body with which the truck is equipped is unsuitable for carrying the material which is to be hauled.

TABLE XI.—*Reasons for using horses for hauling on the road.*

Reasons for using horses.	Number reporting.	Per cent of total.	Reasons for using horses.	Number reporting.	Per cent of total.
Poor roads	219	71	Truck too light	8	3
Truck body unsuitable	42	14	Keep horses busy	3	1
Truck busy	12	4	Other	21	7

It was not possible from the reports to determine the exact proportion of the road hauling which is still done by horses on these farms. However, on a large percentage of them horses are used only for hauling which it is necessary to do when the roads are in such condition that the trucks can not be used, and such hauling would ordinarily amount to only a small percentage of the total. The size of loads and distance hauled with horses are approximately the same as given in Tables V to VIII.

HAULING ON THE FARM WITH TRUCKS.

Of 352 men who reported on the use of their trucks for hauling on the farm (i. e., in the fields and around the buildings), 199, or 57 per cent, stated that they do not use their trucks at all for such work. The reasons for not using the truck for hauling on the farm was not given in every case, but a large number stated that their trucks were not suitable for such work. The smaller trucks in many cases will not carry as large loads as it is desired to haul; often the truck can not obtain traction in the fields, and sometimes the body with which it is equipped is not suitable for some of the hauling on the farm.

Many others stated that they used their horses for all hauling on the farm because there was no advantage in using the truck for such work. Most of the time required for hauling on the farm is taken up with loading and unloading, and the percentage of the total time

which will be saved by the truck when used for such work is small as compared with the time it will save in road hauling. When there are horses on the farm which would otherwise be idle, it would naturally be more profitable to use the horses and let the truck stand idle if there is no advantage in time saved or convenience in using it.

The reasons for using their trucks as given by 145 of the men who reported that they did some hauling on their farms with their trucks are summarized in Table XII. Most of this hauling was crops. (See fig. 3.) In all, 105 men reported that they hauled some crops in the fields with their trucks, and a much smaller number reported the

FIG. 3.—Unloading grain from a truck. The motor truck can often be used advantageously for hauling grain from the separator to the granary.

hauling of any other material in the fields and around the buildings. These men who used their trucks for hauling crops on the farm hauled only 48 tons per year on the average. For all farms an average of 83 tons of crops are hauled to market per year. Thus even the men who do use their trucks for hauling on the farm do only a small portion of all the hauling in the fields and around the buildings with them.

TABLE XII.—*Reasons for using truck for hauling on the farm.*

Reasons for using truck.	Number reporting.	Per cent of total.
Time saved	82	56
Convenience	40	28
Horses busy	12	8
Other	11	8

Fifty-six per cent of these men gave the saving of time as the reason for using trucks for this hauling. The average length of haul with trucks on the farm was about 235 rods. A truck will save some time over horses on hauls of this length if there is no difficulty in obtaining traction in the fields. It may also save time to use a truck if only one or two loads are to be hauled and the horses and wagons are not ready for use.

Twenty-eight per cent use trucks for some hauling on the farm, because they have found their trucks more convenient than horses. When frequent stops must be made, or when the truck or wagon must be left without attention for a considerable length of time, the truck may be preferable, even though the horses are allowed to remain idle, and the use of the truck does not save any time.

The men whose trucks are equipped with pneumatic tires evidently use them to a somewhat greater extent for hauling on the farm than do the men whose trucks are equipped with solid tires. For instance, 252 owners of 1-ton trucks reported concerning the use of their trucks in hauling on the farm. Forty-eight of them have solid-tired trucks, and only 20 of these 48 used their trucks for any hauling on the farm. One hundred and sixty-nine have trucks with pneumatic tires in front and solids in the rear, and only 71 used their trucks for any hauling on the farm. The remaining 35 have pneumatic-tired trucks and 20 used them for some hauling on the farm. Thus only a little over 40 per cent of the 1-ton trucks equipped with solid tires and of those equipped with pneumatics in front and solids in rear were used for work on the farm, while better than 55 per cent of those equipped with pneumatic tires were used for such work.

CUSTOM HAULING.

Although all of these men use their trucks primarily for hauling to and from their own farms, about 40 per cent of them did some custom work during the year preceding the time of reporting. Of 504 who reported on this item, 295 stated that they had done no custom work. One hundred and eighty-nine of the remaining 209 received on the average $132 for such work during the year. The number who reported hauling different materials and the price per ton-mile are given in Table XIII. It is seen that most of this hauling was either crops or live stock. On the average the men who hauled crops hauled 35 tons a distance of 9½ miles during the year, and the men who hauled live stock hauled 12 tons a distance of 18½ miles.

About 35 per cent stated that the custom work which they did had not been profitable. It was often stated that the principal reason for doing custom work was to accommodate the neighbors, and in many such cases the price was too low to make the work profitable.

TABLE XIII.—*Price received for custom work.*

Material.	Number of reports.	Price per ton-mile.
Crops	103	$0.38
Live stock	119	.46
Building material	22	.38
Fuel	30	.32
Other	46	.53

EFFECT OF DIFFERENT KINDS OF ROADS ON USE OF TRUCKS.

It has been shown that the majority of these farmers considered poor roads the greatest disadvantage in the use of a motor truck, and that most of those who still use horses for part of their road hauling do so because of poor roads. In order to gain a more definite idea of the effect of the kind of roads on the use of motor trucks each farmer was asked to specify the kinds of roads over which his truck traveled and the number of weeks during the past year the roads had been in such condition on account of mud, snow, ice, or frost that the truck could not be used.

All kinds of roads, from unimproved dirt roads to high-class highways, were reported. However, 80 per cent of the men who reported on this point stated that their trucks ordinarily travel only on dirt roads, and 14 per cent stated that the roads which they ordinarily use are part dirt and part improved, and the remainder stated that they have only improved roads, either gravel, macadam, or better.

On the average there were 8.4 weeks during the year when the trucks could not be used, and only about 6 per cent of the men reported that they were able to use their trucks every week. The men whose trucks usually travel on improved roads only, however, were prevented from using them but five weeks during the year, and over one-fourth were able to use them every week.

The reports indicate that poor roads are not such a great handicap to pneumatic-tired trucks as to those equipped with solid tires. Table XIV shows the average number of weeks per year trucks with different kinds of tires on roads which are all or part dirt could not be used.

TABLE XIV.—*Effect of kind of tires on length of time trucks could not be used on roads which are all or part dirt.*

Kind of tires.	Number reporting.	Average number of weeks trucks could not be used.
Pneumatic	152	6.6
Solid	211	9.4
Pneumatic in front, solid in rear	338	9.1

The exact number of weeks these men who have roads which are all or part dirt could not use their trucks is as follows:

Of 152 men who use pneumatic tires—
- 15 were able to use their trucks every week in the year.
- 58 were unable to use them for 1 to 4 weeks in the year.
- 37 were unable to use them for 5 to 8 weeks in the year.
- 25 were unable to use them for 9 to 12 weeks in the year.
- 7 were unable to use them for 13 to 16 weeks in the year.
- 7 were unable to use them for 17 to 20 weeks in the year.
- 3 were unable to use them for 21 weeks or more.

Of 211 men who use solid tires—
- 3 were able to use their trucks every week in the year.
- 56 were unable to use them for 1 to 4 weeks in the year.
- 55 were unable to use them for 5 to 8 weeks in the year.
- 48 were unable to use them for 9 to 12 weeks in the year.
- 28 were unable to use them for 13 to 16 weeks in the year.
- 8 were unable to use them for 17 to 20 weeks in the year.
- 13 were unable to use them for 21 weeks or more.

Of 338 men who use pneumatic tires in front and solid tires in the rear—
- 15 were able to use their trucks every week in the year.
- 82 were unable to use them for 1 to 4 weeks in the year.
- 96 were unable to use them for 5 to 8 weeks in the year.
- 77 were unable to use them for 9 to 12 weeks in the year.
- 27 were unable to use them for 13 to 16 weeks in the year.
- 28 were unable to use them for 17 to 20 weeks in the year.
- 13 were unable to use them for 21 weeks or more.

Ten per cent of these men who have pneumatic-tired trucks were able to use them every week in the year, and less than 30 per cent were laid up for more than eight weeks by poor roads. Less than 2 per cent of the men whose trucks were equipped with solid tires were able to use them every week, and over 45 per cent of them were laid up for more than eight weeks.

Forty-five men who have all improved roads reported the kind of tires with which their trucks are equipped. Two of them are equipped with pneumatic tires, 3 with solid tires, and 40 with pneumatics in front and solids in rear.

The number of weeks during the year these 45 trucks could not be used is as follows:

- 12 could be used every week.
- 16 could not be used for 1 to 4 weeks.
- 6 could not be used for 5 to 8 weeks.
- 7 could not be used for 9 to 12 weeks.
- 4 could not be used for 13 or more weeks.

It does not necessarily follow that horses were always used for hauling when the roads were in such a condition that the trucks could not be used, as on at least a part of these farms there was no hauling which it was necessary to do at such times.

CHANGE OF MARKET.

Each of these men was asked for the name of the town where he usually marketed his produce before the purchase of his truck and its distance from the farm. He was also asked to give the name of the town where the produce hauled by truck is usually marketed and its distance from the farm. The answers of 814 men to these questions show that 215, a little over one-fourth of the entire number, have changed markets since purchasing trucks. For these 215 farmers the average distance to the old market was 6.9 miles, and the average distance to the new market is 17.6 miles. Practically all of these men stated that they have changed markets because the new market is better than the old one. It should be remembered that a considerable number of those who have not changed markets were using first-class markets before they purchased trucks.

The distances from these farms to the markets which they used before buying their trucks and the distances to the markets which they are now using are as follows:

Of 60 men who formerly used markets 1 to 4 miles distant—
- 8 now use markets 1 to 4 miles distant.
- 21 now use markets 5 to 9 miles distant.
- 13 now use markets 10 to 14 miles distant.
- 6 now use markets 15 to 19 miles distant.
- 3 now use markets 20 to 24 miles distant.
- 2 now use markets 25 to 29 miles distant.
- 3 now use markets 30 to 34 miles distant.
- 2 now use markets 35 to 39 miles distant.
- 2 now use markets 40 or more miles distant.

Of 112 men who formerly used markets 5 to 9 miles distant—
- 24 now use markets 5 to 9 miles distant.
- 37 now use markets 10 to 14 miles distant.
- 14 now use markets 15 to 19 miles distant.
- 5 now use markets 20 to 24 miles distant.
- 8 now use markets 25 to 29 miles distant.
- 9 now use markets 30 to 34 miles distant.
- 5 now use markets 35 to 39 miles distant.
- 10 now use markets 40 or more miles distant.

Of 33 men who formerly used markets 10 to 14 miles distant—
- 1 now uses markets 5 to 9 miles distant.
- 9 now use markets 10 to 14 miles distant.
- 12 now use markets 15 to 19 miles distant.
- 2 now use markets 20 to 24 miles distant.
- 2 now use markets 25 to 29 miles distant.
- 2 now use markets 30 to 34 miles distant.
- 1 now uses markets 35 to 39 miles distant.
- 4 now use markets 40 or more miles distant.

Of 8 men who formerly used markets 15 to 19 miles distant—
- 4 now use markets 15 to 19 miles distant.
- 4 now use markets 20 to 24 miles distant.

Of 2 men who formerly used markets 20 or more miles distant—
- 1 now uses markets 20 to 24 miles distant.
- 1 now uses markets 25 to 29 miles distant.

The fact that a man has changed his market does not necessarily mean that he hauls all of his produce to the new market or that he purchases all of his supplies from that place. In fact, a considerable number still haul some material either to or from the old market.

Before they purchased trucks 80 per cent of these 215 men used markets which were less than 10 miles from their farms, but now 75 per cent of them are using markets which are 10 miles or more distant. One hundred and two of them now use markets which are 15 miles or more from their farms, yet only 159 of the entire 814 are using markets which are 15 miles or more from their farms. Thus two-thirds of all the men who now use markets which are so far from their farms are men who have changed markets since purchasing trucks.

ANNUAL USE OF TRUCKS.

The number of miles per year which a truck travels has a direct bearing on the cost per mile run or per ton hauled. Depreciation, interest, and repairs are all more or less independent of the number of miles per year which a truck runs, and the greater the number of miles traveled per year the less will be the cost per mile for these items. Table XV gives the average of the estimates of the days per year on which they are used and the number of miles traveled per year for trucks of different sizes. The days per year on which the truck is used does not mean the number of full days' work which the truck does, but simply the number of days during the year on which some use was found for it.

TABLE XV.—*Annual use of trucks of different sizes.*

Size of truck.	Days per year on which truck is used.		Miles traveled per year.	
	Days.	Number of estimates.	Miles.	Number of estimates.
½-ton and ¾-ton	170	54	3,928	62
1-ton	112	447	2,630	385
1¼-ton and 1½-ton	90	81	2,570	82
2-ton	86	45	2,837	41
All	112	627	2,777	570

In general the smaller trucks are used on a greater number of days and travel a greater number of miles per year. However, the individual reports show that there is no very close relation between the size of the truck and the miles traveled per year. For the farms under consideration the amount of material to be hauled, the length of haul, and the size of truck are all corelated in such a way that no one factor exerts a predominant influence.

The exact number who estimated that their trucks travel different distances per year is as follows:

38, or 7 per cent, estimated the annual mileage at 750 or less.
150, or 26 per cent, estimated the annual mileage at 751 to 1,750.
155, or 27 per cent, estimated the annual mileage at 1,751 to 2,750.
91, or 16 per cent, estimated the annual mileage at 2,751 to 3,750.
51, or 9 per cent, estimated the annual mileage at 3,751 to 4,750.
37, or 7 per cent, estimated the annual mileage at 4,751 to 5,750.
14, or 2 per cent, estimated the annual mileage at 5,751 to 6,750.
11, or 2 per cent, estimated the annual mileage at 6,751 to 7,750.
11, or 2 per cent, estimated the annual mileage at 7,751 to 8,750.
12, or 2 per cent, estimated the annual mileage at 8,751 or more.

LIFE AND DEPRECIATION OF TRUCKS.

The average first cost, life, and depreciation per year and per mile of travel for the trucks of different sizes are shown in Table XVI:

TABLE XVI.—*First cost, life, and depreciation charges for trucks of different sizes.*

[Figures in parentheses indicate the number of reports for respective items.]

	Size of truck.			
	½-ton and ¾-ton.	1-ton.	1¼-ton and 1½-ton.	2-ton.
First cost	$1,418 (71)	$929 (582)	$1,809 (106)	$2,052 (56)
Extra equipment	29 (57)	49 (489)	52 (83)	77 (46)
Total cost	1,447	978	1,861	2,129
Present age (years)	1.3 (74)	1.3 (588)	1.4 (109)	1.4 (60)
Remaining life (years)	4.6 (37)	4.9 (337)	6.4 (58)	6.0 (30)
Total life (years)	5.9	6.2	7.8	7.4
Annual depreciation	$245	$158	$239	$288
Miles traveled per year	3,928 (62)	2,630 (385)	2,570 (82)	2,837 (41)
Depreciation per mile of travel	$0.062	$0.060	$0.093	$0.102

The quoted price of the truck often does not include some equipment which it is necessary or desirable to have, and each man was asked to report not only the first cost of his truck but also the cost of any extra equipment he had purchased for it. It was found that about two-thirds of the men had bought some equipment which was not included in the quoted price. This extra equipment varied from minor attachments costing only $2 or $3 to bodies and cabs costing as much as $200 or $300. As shown in the table, the amount spent for this extra equipment has been added to the reported first cost to obtain the total cost.

Three men reported that they own trailers for use with their motor trucks. However, the cost of these trailers was not included in the total cost of the trucks.

The total life of the trucks was figured by adding the present age—that is, the average number of years which the trucks had been owned—to the average of the estimates of the remaining number of years for which the trucks will give satisfactory service. The re-

maining life of the truck depends not only upon its present condition but also upon the probable work it will do in the future and the owner's idea as to when it will be cheaper to discard it and purchase a new one than to spend more time and money on it for repairs. There is quite a wide variation in the individual estimates on this item, but the average life as obtained in this manner gives the best available basis for figuring depreciation costs. The average life of all trucks as figured by this method is 6.5 years.

The annual depreciation was figured by dividing the first cost by the life in years, and depreciation per mile of travel by dividing the annual depreciation by the average number of miles traveled per year. A comparison of these figures with those for the cost of fuel and oil in Table XVIII and for tires in Table XIX shows that for each size the depreciation charge is greater than the combined costs of fuel, oil, and tires.

REPAIRS.

Each truck owner was asked to report the amount he had spent for repairs since the purchase of his truck. A summary of the replies for trucks of different sizes and ages is given in Table XVII.

TABLE XVII.—*Average repair cost of trucks of different sizes and ages.*

Present age (months owned).	Size of truck.			
	½ and ¾-ton.	1-ton.	1¼ and 1½-ton.	2-ton.
	Average total expense for repairs.			
12 and less	$9	$13	$11	$14
13 to 24	38	26	28	35
25 to 36	41	62	32	31

The amounts which the owners of trucks of different sizes had spent are as follows:

One-half ton and three-fourths ton trucks:

Of 43 men who had used their trucks 12 months or less—
- 24 had spent nothing for repairs.
- 15 had spent from $1 to $37.
- 4 had spent from $38 to $87.

Of 18 men who had used their trucks 13 to 24 months—
- 4 had spent nothing for repairs.
- 9 had spent from $1 to $37.
- 3 had spent from $38 to $87.
- 0 had spent from $88 to $137.
- 2 had spent $138 or more.

Of 4 men who had used their trucks 25 to 36 months—
- 1 had spent nothing for repairs.
- 1 had spent from $1 to $37.
- 1 had spent from $38 to $87.
- 1 had spent from $88 to $137.

1-ton trucks:

Of 262 men who had used their trucks 12 months or less—
122 had spent nothing for repairs.
118 had spent from $1 to $37.
14 had spent from $38 to $87.
4 had spent from $88 to $137.
4 had spent $138 or more.

Of 261 men who had used their trucks 13 to 24 months—
51 had spent nothing for repairs.
154 had spent from $1 to $37.
38 had spent from $38 to $87.
9 had spent from $88 to $137.
9 had spent $138 or more.

Of 36 men who had used their trucks 25 to 36 months—
2 had spent nothing for repairs.
18 had spent from $1 to $37.
10 had spent from $38 to $87.
2 had spent from $88 to $137.
4 had spent $138 or more.

1¼ and 1½-ton trucks:

Of 36 men who had used their trucks 12 months or less—
23 had spent nothing for repairs.
9 had spent from $1 to $37.
3 had spent from $38 to $87.
0 had spent from $88 to $137.
1 had spent $138 or more.

Of 56 men who had used their trucks 13 to 24 months—
19 had spent nothing for repairs.
24 had spent from $1 to $37.
8 had spent from $38 to $87.
2 had spent from $88 to $137.
3 had spent $138 or more.

Of 7 men who had used their trucks 25 to 36 months—
1 had spent nothing for repairs.
3 had spent from $1 to $37.
2 had spent from $38 to $87.
1 had spent from $88 to $137.

2-ton trucks:

Of 24 men who had used their trucks 12 months or less—
10 had spent nothing for repairs.
10 had spent from $1 to $37.
4 had spent from $38 to $87.

Of 26 men who had used their trucks 13 to 24 months—
2 had spent nothing for repairs.
14 had spent from $1 to $37.
7 had spent from $38 to $87.
3 had spent from $88 to $137.

Of 5 men who had used their trucks 25 to 36 months—
2 had spent nothing for repairs.
2 had spent from $1 to $37.
0 had spent from $38 to $87.
1 had spent from $88 to $137.

In all, about 50 per cent of the men who had owned their trucks 12 months or less had spent nothing for repairs, but comparatively few of the men who had owned their trucks for more than a year had been free from expense for repairs. Ordinarily the amount which must be spent for repairs during the latter years of a truck's life will be considerably greater than the cost for the first two or three years. None of these trucks is entirely worn out, and it is not possible from the reports to obtain an accurate figure as to the average annual repair cost for the entire life of a truck. In the absence of accurate figures, allowances of $75 per year for the ½-ton and ¾-ton trucks, $75 for the 1-ton trucks, $100 for the 1¼-ton and 1½-ton trucks, and $150 for the 2-ton trucks have been made as fair charges for the average annual repair costs in figuring the cost of operation in Table XXII. (For the repair costs of some trucks which have been in use three years and longer see Department Bulletin 910, "Experience of Eastern Farmers with Motor Trucks."

GASOLINE AND OIL.

The average number of miles obtained per gallon of gasoline and per quart of cylinder oil by the men who use trucks of different sizes are shown in Table XVIII. The average price which these men paid for gasoline at the time they made their reports (January to March, 1920) was 26 cents per gallon, and the average price of lubricating oil was 70 cents per gallon. The costs per mile traveled are computed from these figures. No attempt was made to learn the amount and value of the grease used, but in any case its value should be only a fraction of that of the lubricating oil.

TABLE XVIII.—*Gasoline and oil requirements of trucks of different sizes.*

[Gasoline, 26 cents per gallon; lubricating oil, 70 cents per gallon. Figures in parentheses indicate number of reports for respective items.]

Size of truck.	Miles per gallon of gasoline.	Cost per mile.	Miles per quart of oil.	Cost per mile.	Total cost per mile for gasoline and oil.
½-ton and ¾-ton	11.8 (69)	$0.022	80 (55)	$0.002	$0.024
1-ton	10.5 (557)	.025	46 (488)	.004	.029
1¼-ton and 1½-ton	9.7 (102)	.027	52 (88)	.003	.030
2 ton	8.0 (57)	.032	38 (48)	.005	.037

TIRES.

Each man was asked to state what he paid for tires and the mileage obtained. The tire cost per mile as shown in Table XIX was figured by simply dividing the average cost of one tire by the average number of miles which the tire run and multiplying this result

by 4 to get the cost for four tires. According to the estimates of 310 men the pneumatic tires on these trucks run on the average 4,400 miles, and the estimates of 161 men show that the solid tires run 7,700 miles. So few of the ½ and ¾-ton trucks are equipped with solid tires and so few of the owners of 1¼-ton and 1½-ton trucks reported concerning the cost and mileage of solid tires that no figures for solid tires for these sizes are given.

Since the cost of the tires with which a truck is equipped when purchased is included in the first cost of the truck, an allowance must be made for the number of miles which these tires run in order to determine the net tire cost to the user.

According to the estimates of these men the percentage of the total mileage of the trucks obtained from the tires with which they are equipped when purchased is as follows:

Pneumatic tires on the ½-ton and ¾-ton trucks run 23 per cent of the total mileage.

Pneumatic tires on the 1-ton trucks run 25 per cent of the total mileage.

Solid tires on the 1-ton trucks run 48 per cent of the total mileage.

Pneumatic tires on the 1¼-ton and 1½-ton trucks run 29 per cent of the total mileage.

Pneumatic tires on the 2-ton trucks run 22 per cent of the total mileage.

Solid tires on the 2-ton trucks run 36 per cent of the total mileage.

The cost per mile as indicated by the cost of tires and the number of miles which they run has been reduced by these percentages in order to obtain the net cost per mile traveled. No attempt was made to ascertain the cost of inner tubes for pneumatic tires, nor to obtain the cost of tire repairs separately from the entire repair costs of the trucks.

TABLE XIX.—*Tire costs.*

Size of truck.	Kind of tires.	Cost per mile.	Allowance for tires on machine when bought.	Net cost per mile.
½-ton and ¾-ton	Pneumatic (52 reports)	$0.039	$0.009	$0.030
1-ton	Pneumatic (290 reports)	.023	.006	.017
1-ton	Solid (79 reports)	.022	.011	.011
1¼-ton and 1½-ton	Pneumatic (27 reports)	.030	.009	.021
2-ton	Pneumatic (14 reports)	.043	.009	.034
2-ton	Solid (14 reports)	.038	.014	.024

KINDS OF TIRES RECOMMENDED BY USERS.

These truck owners were asked what kind of tires they consider best for their conditions, regardless of the kind they are now using. The kinds of tires which 684 men with trucks of all sizes are now using and the kinds which they have decided are best are as follows:

Of 161 men who now use pneumatic tires—
159 prefer pneumatics.
2 prefer solids.
Of 187 men who now use solid tires—
49 prefer pneumatics.
136 prefer solids.
2 prefer pneumatics in front and solids in rear.
Of 336 men who now use pneumatics in front and solids in rear—
191 prefer pneumatics.
100 prefer solids.
45 prefer pneumatics in front and solids in rear.

In all 24 per cent now use pneumatics, 27 per cent use solids, and 49 per cent use pneumatics in front and solids in the rear. However, experience has caused 58 per cent to decide that pneumatics are best for their conditions, 35 per cent that solids are best, and 7 per cent that pneumatics in front and solids in rear are best.

The kind of tires which a man considers best depends considerably on the size of his truck. The kinds which the owners of machines of different sizes prefer are as follows:

Of 70 owners of ½-ton and ¾-ton trucks—
64 prefer pneumatics.
6 prefer solids.
Of 481 owners of 1-ton trucks-
279 prefer pneumatics.
162 prefer solids.
40 prefer pneumatics in front and solids in rear.
Of 90 owners of 1¼-ton and 1½-ton trucks—
44 prefer pneumatics.
42 prefer solids.
4 prefer pneumatics in front and solids in rear.
Of 43 owners of 2-ton trucks—
12 prefer pneumatics.
28 prefer solids.
3 prefer pneumatics in front and solids in rear.

RELIABILITY.

The reliability of a motor truck, as that of any other machine, has a very decided effect upon its profitableness. If a truck is out of commission for several days at a time when its services are needed and when its owner is depending upon it to help him through a busy time it can scarcely be considered a profitable machine for him to own. Likewise, if a great deal of time is lost on the road on account of motor and tire trouble, breakage, and other mechanical difficulties, this loss and annoyance may overcome all the advantages attending its use.

In order to obtain information as to the reliability of motor trucks for farm use these truck owners were asked to give both the number of days their trucks had been out of commission when needed during the past year and the percentage of the time lost while using them.

Table XX shows the average number of days 784 trucks of different ages were out of commission during the year preceding the time of reporting:

TABLE XX.—*Days trucks of different ages were out of commission when needed.*

Age of trucks (months).	Total number of reports.	Average days out of commission.
12 and less	374	0.8
13 to 24	354	2.0
25 and over	56	2.3
All	784	1.4

The total number of days the trucks of different ages were out of commission is as follows:

Of 374 which had been in use 12 months or less—
- 333 were out of commission no days.
- 24 were out of commission 1 to 5 days.
- 13 were out of commission 6 to 10 days.
- 4 were out of commission over 10 days.

Of 354 which had been in use 13 to 24 months—
- 281 were out of commission no days.
- 44 were out of commission 1 to 5 days.
- 19 were out of commission 6 to 10 days.
- 10 were out of commission over 10 days.

Of 56 which had been in use 25 months or more—
- 43 were out of commission no days.
- 7 were out of commission 1 to 5 days.
- 1 was out of commission 6 to 10 days.
- 5 were out of commission over 10 days.

Eighty-four per cent of the trucks had not been out of commission at all when needed, 9 per cent had been out of commission five days or less, and 7 per cent had been out of commission over five days. In general, the newer trucks are somewhat more reliable than the older ones. Practically 90 per cent of those which had been in use 12 months or less had not been out of commission when needed.

The average percentage of time lost on account of motor and tire trouble, breakage, and other mechanical difficulties, by 636 men owning trucks of different ages is given in Table XXI.

TABLE XXI.—*Per cent of time lost by trucks of different ages.*

Age of trucks (months).	Total number of reports.	Average per cent of time lost.
12 and less	305	0.5
13 to 24	285	1.2
25 and over	46	0.6
All	636	0.8

The loss reported by men who had used their trucks different lengths of time is as follows:

Of 305 who had used their trucks 12 months or less—
- 260 reported the loss of no time.
- 40 reported the loss of 1 to 5 per cent.
- 4 reported the loss of 6 to 10 per cent.
- 1 reported the loss of more than 10 per cent.

Of 285 who had used their trucks 13 to 24 months—
- 215 reported the loss of no time.
- 60 reported the loss of 1 to 5 per cent.
- 5 reported the loss of 6 to 10 per cent.
- 5 reported the loss of more than 10 per cent.

Of 46 who had used their trucks 25 months or more—
- 31 reported the loss of no time.
- 15 reported the loss of 1 to 5 per cent.

Eighty per cent of these men stated that they had lost no appreciable time on account of motor and tire trouble and other mechanical difficulties, and only about 1 in 40 reported a loss of more than 5 per cent. As the trucks grow older the amount of time lost and the number of days out of commission will become greater, but farmers in the Eastern States whose trucks have been in use longer than most of these do not often report any serious loss (see Department Bulletin 910, "Experience of Eastern Farmers with Motor Trucks.")

The average length of haul for these corn-belt truck owners is about 9 miles, and the average time required for the round trip is not far from 2½ hours. (See Tables V to VIII.) A loss of 10 per cent of the time on the average trip would mean a delay of only about 15 minutes. Such delays even with the trucks which give the most trouble would scarcely be as serious as the loss due to having a truck out of commission for several days when it is needed.

To a certain extent the reliability of a motor truck, as of any other complicated machine, depends upon the ability of the operator, and the care which the machine is given. About 90 per cent of these trucks are operated by their owners, or some member of the family, and it is to be expected that the owner of such an expensive machine as a motor truck, or any member of his family, would give it a reasonable amount of care, and at least endeavor to operate it intelligently. Furthermore, automobiles are owned on 95 per cent of these farms, and tractors on 50 per cent of them. Thus nearly all the men who drive the trucks have doubtless had considerable experience in the operation of similar machines. The exceptionally small amount of trouble which these trucks have given is doubtless due in part to these facts.

COST OF OPERATION.

The average cost of operating trucks of different sizes is given in Table XXII. The items included are depreciation, repairs, interest on investment, registration and license fees, gasoline and oil, and tire cost.

The figures for annual depreciation are obtained from Table XVI, and those for repairs from page 24.

Interest is figured at 6 per cent on the average investment. The average investment has been found by the rule: Average investment=first cost $\times \frac{\text{years of service}+1}{\text{years of service}\times 2}$. This is the generally accepted method for determining the average investment in equipment where a fraction of the first cost is charged off each year for depreciation. The interest charge when computed on this basis is slightly greater than when computed on one-half of the first cost.

The registration and the license fees are the averages of those reported for the year of 1920 by the owners. These fees vary considerably in the different States.

The number of miles traveled per year are obtained from Table XV, the gasoline and oil costs from Table XVIII, and the tire cost from Table XIX. The tire costs used are those for pneumatic tires for each size. In no case is the average cost for solid tires more than 1 cent per mile different from the pneumatic tire costs.

No charge has been made for taxes, insurance, housing, or for labor spent in caring for the truck. However, these charges would ordinarily amount to a very small portion of the total cost of operation.

TABLE XXII.—*Cost of operating trucks of different sizes.*

	Size.			
	½-ton and ¾-ton.	1-ton.	1¼-ton and 1½-ton.	2-ton.
Fixed charges:				
Annual depreciation	$245	$158	$239	$288
Annual repairs	75	75	100	150
Annual interest	51	34	63	73
Annual registration and license fee	15	12	14	20
Total fixed charges	386	279	416	531
Miles traveled per year	3,928	2,630	2,570	2,837
Fixed charges per mile	$0.098	$0.106	$0.162	$0.187
Gasoline and oil per mile	.024	.029	.030	.037
Tires per mile	.030	.017	.021	.034
Total cost per mile	.152	.152	.213	.258

COST OF HAULING WITH TRUCKS.

The cost of hauling with a motor truck is determined by the cost of operating the truck, the charge for the driver's time and labor, the size of load hauled, and the percentage of time the truck runs without a load. In Table XXIII are given the cost per mile of haul and the cost per ton-mile of hauling crops with trucks of different sizes. The cost of operating the truck is taken directly from the preceding table. The charge for the driver is obtained by allowing a rate of 50 cents per hour for his time while driving and while loading and unloading the truck. The average time required for hauling different materials as given in Tables V to VIII is 0.12 hour per mile of travel for each size of truck.

It is stated on page 13 that these men have return loads for their trucks about 34 per cent of the time; that is, each truck hauls loads both ways on 34 out of every 100 round trips it makes from and to the farm, and runs without a load 66 one-way trips. The cost of operating the truck and the value of the driver's time for these 66 trips with no load must be charged to the 134 trips with loads, in order to obtain the actual cost per mile of haul. Every 134 miles of haul, then, must bear the expense of 200 miles of travel, or every 67 miles of haul must bear the expense of 100 miles of travel. The cost per mile of haul as given in the table is obtained by multiplying the total cost per mile traveled by 100 and dividing the product by 67.

The cost per ton-mile hauled is determined by dividing the cost per mile hauled by the weight of the load in tons. As shown in Table V the average weight of the load of crops hauled with the ½-ton and ¾-ton trucks is 1.326 tons; for 1-ton trucks the average load is 1.313 tons; for 1¼-ton trucks and 1½-ton trucks 1.745 tons; and for 2-ton trucks 2.204 tons. The costs per mile of haul for the trucks of different sizes divided by these figures give the costs per ton-mile.

TABLE XXIII.—*Cost of hauling crops with trucks of different sizes.*

Size of truck.	½-ton and ¾-ton.	1-ton.	1¼-ton and 1½-ton.	2-ton.
Truck cost per mile run	$0.152	$0.152	$0.213	$0.258
Charge for driver per mile run	.060	.060	.060	.060
Total	.212	.212	.273	.318
Cost per mile of haul (33 per cent idle running)	.316	.316	.407	.475
Cost per ton-mile for hauling crops	.240	.241	.233	.215

SAVING OF HIRED HELP.

The saving of time is given by these men as the greatest advantage in the use of a motor truck; but the saving of time will not be of any financial benefit to a farmer unless he uses the time thus saved on

other work, or unless it enables him to reduce the expense for hired help.

These men were asked whether or not their trucks reduce the expense for hired help, either man or horse, and if so, to estimate the amount thus saved per year. Of 783 men who answered the question as to whether the truck reduces the expense for hired help 612, or 78 per cent, said that it does, and the remaining 171 that it does not.

Three hundred and eighty-five of the 612 estimated the amount thus saved, and the average of these estimates is $209. This figure can scarcely be taken to represent the actual amount which the labor bills of these men have been reduced since purchasing their trucks, but rather as their estimates of the amounts by which their bills would be increased if they did not now own trucks, and if they were doing the same amount of work they are now doing.

There is little difference in the percentage of the owners of trucks of different sizes who say that their trucks reduce the expense for hired help or in the amounts which they estimate the trucks save.

If $209 represents the average saving on the 78 per cent of the farms where the trucks reduce the expense for hired help, the amount saved by the average truck on all farms is $163 (78 per cent of $209).

DISPLACEMENT OF HORSES.

The operators of 637 farms reported the number of work stock they owned before the purchase of trucks, and the number they had disposed of since that time. The number of work stock varied from 3 and 4 head on some of the smaller farms to over 20 on the larger ones. In all 6,264 head were kept on the 637 farms before the purchase of trucks. On 276 farms the number had been reduced since the trucks had been purchased by a total of 763. For all farms, this represents a reduction of a little over 12 per cent, and an average displacement of 1.2 head per truck.

Ordinarily the purchase of a truck will not enable a man who owns only 3 or 4 or 5 horses, all of which he sometimes uses as a single unit, to dispose of any. Only 13 of the 87 men who owned less than 6 head reduced their work stock after purchasing trucks.

The number of head owned by different men and the number they disposed of after purchasing trucks are as follows:

Of 87 men who owned less than 6 head before purchasing trucks—
- 74 disposed of none.
- 8 disposed of 1.
- 5 disposed of 2.

Of 134 men who owned 6 or 7 head before purchasing trucks—
83 disposed of none.
4 disposed of 1.
42 disposed of 2.
5 disposed of 3.
Of 126 men who owned 8 or 9 head before purchasing trucks—
70 disposed of none.
6 disposed of 1.
33 disposed of 2.
12 disposed of 3.
5 disposed of 4.
Of 103 men who owned 10 or 11 head before purchasing trucks—
46 disposed of none.
4 disposed of 1.
33 disposed of 2.
13 disposed of 3.
6 disposed of 4.
1 disposed of more than 4.
Of 76 men who owned 12 or 13 head before purchasing trucks—
35 disposed of none.
3 disposed of 1.
12 disposed of 2.
3 disposed of 3.
16 disposed of 4.
7 disposed of more than 4.
Of 111 men who owned 14 or more head before purchasing trucks—
53 disposed of none.
1 disposed of 1.
10 disposed of 2.
5 disposed of 3.
26 disposed of 4.
16 disposed of more than 4.
In all, 57 per cent have disposed of no work stock.
25 per cent have disposed of 1 or 2 head.
14 per cent have disposed of 3 or 4 head.
4 per cent have disposed of 5 or more head.

Evidently the displacement of horses by motor trucks is not as great as the displacement by tractors in the corn belt. Farmers' Bulletin 1093, "Influence of the Tractor on Use of Horses," shows that on 141 corn-belt farms averaging 346 acres in size 2.5 head per farm were disposed of after the purchase of tractors.

FARMS ON WHICH TRACTORS ARE OWNED.

Tractors as well as motor trucks are owned on about half of these farms. However, most of the tractors are on the larger farms. Only 33 per cent of the men with 160 or less crop acres own tractors, while 65 per cent of those with over 320 crop acres own them.

In all, 745 men stated whether they owned tractors and also gave the number of crop acres in their farms. The number of those with

farms of different sizes (*crop* acres, not *total* acres) who do and do not own tractors is as follows:

Of 32 who operate farms of 80 or less crop acres—
4 own tractors.
28 do not own tractors.
Of 211 who operate farms of 81 to 160 crop acres—
77 own tractors.
134 do not own tractors.
Of 189 who operate farms of 161 to 240 crop acres—
103 own tractors.
86 do not own tractors.
Of 153 who operate farms of 241 to 320 crop acres—
88 own tractors.
65 do not own tractors.
Of 74 who operate farms of 321 to 400 crop acres—
48 own tractors.
26 do not own tractors.
Of 38 who operate farms of 401 to 480 crop acres—
25 own tractors.
13 do not own tractors.
Of 22 who operate farms of 481 to 560 crop acres—
13 own tractors.
9 do not own tractors.
Of 26 who operate farms of 561 acres and over—
18 own tractors.
8 do not own tractors.

The ownership of both trucks and tractors has not resulted in any very marked decrease in the number of work stock. Table XXIV shows the number of work stock now owned and the number disposed of since the purchase of trucks on 290 farms of different sizes where tractors are owned. Table XXV shows similar figures for 293 farms where tractors are not owned.

TABLE XXIV.—*Work stock on farms where both trucks and tractors are owned.*

Size of farms (crop acres).	Number of farms.	Present number of work stock per farm.	Reduction since purchase of truck.	Size of farms (crop acres).	Number of farms.	Present number of work stock per farm.	Reduction since purchase of truck.
80 or less	3	4.3	1.3	401 to 480	16	12.1	2.1
81 to 160	65	5.6	1.4	481 to 560	11	11.5	1.9
161 to 240	81	7.7	1.4	561 and over	13	20.5	1.2
241 to 320	63	8.8	1.3				
321 to 400	38	10.2	1.5	All	290	8.7	1.4

TABLE XXV.—*Work stock on farms where trucks, but not tractors, are owned.*

Size of farms (crop acres).	Number of farms.	Present number of work stock per farm.	Reduction since purchase of truck.	Size of farms (crop acres).	Number of farms.	Present number of work stock per farm.	Reduction since purchase of truck.
80 and less	19	4.2	0.7	401 to 480	8	12.9	2.4
81 to 160	110	6.2	0.7	481 to 560	9	15.2	1.7
161 to 240	66	8.0	1.3	561 and over	7	19.1	0.3
241 to 320	52	10.2	1.0				
321 to 400	22	13.1	1.1	All	293	8.5	1.0

Only 5 of the 68 men who have farms of 160 or less crop acres and who own both trucks and tractors are farming with less than four horses. None of the 81 men who have farms of 161 to 240 crop acres is farming with less than four horses, and only 8 are farming with less than six horses. Four of the 63 men with farms of 241 to 320 crop acres, and 1 of the 38 men with farms of 321 to 400 crop acres, are farming with less than six horses.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 932

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER September 20, 1921

LIFE HISTORY OF THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

By E. H. Siegler, *Entomologist*, and H. K. Plank, *Scientific Assistant, Fruit Insect Investigations*, in cooperation with The Colorado Agricultural Experiment Station.

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INTRODUCTION.

The codling moth, *Laspeyresia pomonella* (L.) (Pl. I, A) is generally recognized as the most serious insect pest attacking the fruit of the apple and pear and is particularly abundant and destructive in the Grand Valley of Colorado. As a result of the extensive injury to the fruit industry of this valley for which this insect is responsible, it was deemed desirable to make a thorough study of its life history as a basis for control experiments.

The data reported in the present publication fill an urgent need of long standing for more complete and useful information regarding the seasonal habits of the codling moth in the Grand Valley of Colorado. It should form a basis for constructive control measures for the use of orchardists in this region.

The plans for this investigation were made by the United States Department of Agriculture, Bureau of Entomology, in cooperation with the Colorado Agricultural Experiment Station. The work was done under the general supervision of Dr. A. L. Quaintance, in charge of deciduous fruit insect investigations, Bureau of Entomology, and Prof. C. P. Gillette, director and entomologist of the Colorado Agricultural Experiment Station.

A field station was established at Grand Junction, Colo., in the fall of 1914, by Mr. R. J. Fiske, of the Bureau of Entomology. The senior author was placed in immediate charge of the work in 1915, and was assisted during the year by Mr. E. R. Van Leeuwen, of the Bureau of Entomology, and in 1916 by the junior author. Much valuable information was given from time to time by Messrs. George M. List and Claude Wakeland, of the entomological department of the Colorado Agricultural Experiment Station.

The general character of the work in the Grand Valley was quite similar to that of the codling-moth investigations conducted by the Bureau of Entomology in several other fruit districts, but it was carried out on a somewhat larger scale and includes certain phases of the life history and habits of the codling moth not hitherto reported.

THE GRAND VALLEY OF COLORADO.

LOCATION AND DESCRIPTION.

The Grand Valley of Colorado is located in Mesa County, on the western slope of the Rocky Mountains, is about 32 miles in length, and has an extreme width of 5 miles. It comprises nearly 75,000 acres of land, about one-fifth of which is planted to fruit. At the time of these investigations there were approximately 10,000 acres of apples and about 2,500 acres of pears, while the remainder of the fruited area was devoted chiefly to peaches, plums, cherries, apricots, and bush fruits. The great majority of the orchards, of which the one shown in Plate II is a good example, were planted north of the Grand River, which flows through the entire length of the valley.

TOPOGRAPHY AND ELEVATION.

The valley is comparatively level, with the exception of a few elevations known locally as the "Fruit Ridges." The fruit district of Orchard Mesa, while higher than most other parts of the valley, is typical tableland. The general elevation of the Grand Valley

varies from about 4,500 to 4,800 feet, Grand Junction being approximately 4,600 feet above sea level.

CLIMATE.

The climate is relatively dry, the annual rainfall being usually 8 to 9 inches, distributed according to the normal precipitation up to and including 1916 as follows: January 0.49, February 0.64, March 0.71, April 0.76, May 0.92, June 0.40, July 0.50, August 1.04, September 0.95, October 0.91, November 0.55, December 0.44, or a total of 8.31 inches per year. Moisture is supplied the crops by means of irrigation systems, use being made of the water from the Grand River.

The day temperatures during the summer season are high, while those at night are relatively low. For further details as to weather conditions in the Grand Valley see Tables I and II (pp. 4 and 5), which give the annual meteorological summaries of the United States Weather Bureau for the years 1915 and 1916.

EXPLANATION OF TERMS.

In conformity with the previous life-history studies of the codling moth by members of the Bureau of Entomology, certain definitions of the terms employed have been adopted.

The term "generation" is here used to include all the consecutive stages of the codling moth throughout the season, starting with the egg and ending with the adult or moth. Thus the first eggs to be laid (those deposited by the first moths of the season) would start the first generation; these and the resulting larvæ, pupæ, and moths would belong to this generation. The eggs deposited by the moths which belong to the first generation start the second generation, to which also belong the resulting larvæ, pupæ, and moths, and so on.

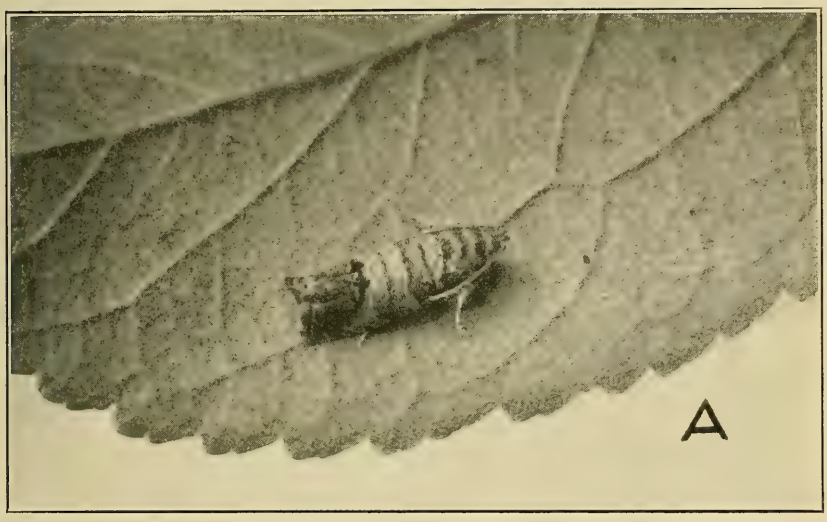
The term "brood" as used in this publication is applied to any stage of the codling moth which may belong to a specific generation or to an unknown generation. For example, the eggs, larvæ, pupæ, and moths which belong to the first generation are called first-brood eggs, larvæ, etc.

The larvæ which pass the winter include all the nontransforming larvæ of the first and second broods, and, in the Grand Valley of Colorado, all of the larvæ of the third brood. The specific generation to which each of these individuals belongs can not be determined unless they have been reared. The term "generation," therefore, can not properly be used to include the various stages of their transformations; they are simply called "wintering" or "spring-brood" larvæ, and the pupæ and moths into which they transform are designated "spring-brood" pupæ and moths.

TABLE I.—*Annual meteorological summary, Grand Junction, Colo., 1915.*

Month.	Temperature (° F.).							Precipitation (inches).			Relative humidity.			Sunshine.		Average cloudiness (scale of 0 to 10).	Wind.			Number of days.										
	Means.			Extremes.																							Max. temp.		Min. temp.	
	Maximum.	Minimum.	Monthly.	Highest.	Date.	Lowest.	Date.	Total.	Greatest in 24 hours.	Total snowfall.	Mean at 6 a. m.	Mean at 6 p. m.	Lowest observed.	Number of hours.	Per cent of possible.		Average velocity (miles per hour).	Prevailing direction.	Maximum velocity (for 5 minutes).	Winds of 40 miles or more per hour.	Clear.	Partly cloudy.	Cloudy.	Precipitation (0.01 inch or more).	Thunderstorms.	Dense fog.	Snowfall (0.01 inch or more melted).	32° or below.	90° or above.	32° or below.	0° or below.
January	31	9	20	41	3	−4	24	0.77	0.28	7.1	93	68	25	193	64	5.5	4.4	W.	21	0	11	8	12	7	0	3	6	19	0	31	4
February	43	2	35	58	11	15	8	0.53	0.29	1.1	86	60	37	166	55	5.5	5.8	W.	39	0	10	7	11	8	0	0	5	0	0	24	0
March	55	32	43	67	26	26	4	0.10	0.10	0.1	63	28	11	256	69	5.1	6.6	W.	48	1	10	14	7	2	0	0	1	0	0	20	0
April	68	45	56	79	28	34	1	1.41	0.47	0	66	34	13	222	56	5.4	8.0	SE.	42	1	8	15	7	11	9	0	0	0	0	0	0
May	70	46	58	88	13	29	2	1.23	0.62	T.	58	30	10	264	60	5.6	8.0	SE.	47	1	9	12	10	10	6	0	0	0	0	2	0
June	82	54	68	93	24	44	4	0.92	0.42	0	46	20	5	377	84	3.0	7.8	E.	45	1	19	7	4	6	5	0	0	0	8	0	0
July	91	64	77	97	11	56	4	0.16	0.13	0	42	20	9	372	82	3.2	8.0	E.	36	0	16	4	1	3	9	0	0	0	19	0	0
August	89	61	75	95	4	54	17	0.51	0.25	0	47	24	8	340	80	2.9	7.9	E.	33	0	19	10	2	7	10	0	0	0	15	0	0
September	78	53	66	90	1	42	14	0.95	0.81	0	56	29	12	275	74	3.8	7.8	SE.	45	1	15	12	3	5	5	0	0	0	1	0	0
October	69	40	54	79	2	33	31	0.01	0.01	0	50	24	12	313	90	2.0	5.9	SE.	29	0	24	5	2	1	0	0	0	0	0	0	0
November	50	28	39	71	5	11	28	0.71	0.27	4.5	66	50	8	230	76	4.9	6.3	E.	43	1	14	6	10	8	1	0	5	0	0	20	0
December	39	22	30	55	14	10	28	1.15	0.38	15.8	85	68	24	164	56	6.3	5.0	SE.	28	0	7	9	15	9	0	0	8	9	0	29	0
Year	64	40	52	97	July 11.	−4	Jan. 24.	8.45	0.81	28.6	63	38	5	3,172	70	4.4	6.8	SE.	48	6	162	119	84	77	45	3	25	28	43	126	4

NOTE.—Precipitation includes rain and melted snow, hail, and sleet. "T." indicates trace of precipitation.



A. ADULT MOTH RESTING ON APPLE LEAF.

B. PAIR OF MOTHS IN COPULA.

THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

View of experimental orchard.

TABLE II.—*Annual meteorological summary, Grand Junction, Colo., 1916.*

Month.	Temperature (° F.).							Precipitation (inches).			Relative humidity.			Sunshine.		Average cloudiness (scale of 0 to 10).	Wind.			Number of days.										
	Means.			Extremes.																								Max. temp.		Min. temp.	
	Maximum.	Minimum.	Monthly.	Highest.	Date.	Lowest.	Date.	Total.	Greatest in 24 hours.	Total snowfall.	Mean at 6 a. m.	Mean at 6 p. m.	Lowest observed.	Number of hours.	Per cent of possible.		Average velocity (miles per hour).	Prevailing direction.	Maximum velocity (for 5 minutes).	Winds of 40 miles or more per hour.	Clear.	Partly cloudy.	Cloudy.	Precipitation (0.01 inch or more).	Thunderstorms.	Dense fog.	Snowfall (0.01 inch or more melted).	32° or below.	90° or above.	32° or below.	0° or below.
January	32	13	22	50	28	−7	31	1.18	0.23	15.2	92	78	36	130	43	7.5	5.2	NW.	51	1	4	8	19	16	0	1	15	16	0	31	2
February	43	21	32	54	24	−9	1	0.45	0.16	1.5	89	68	36	228	73	4.6	4.6	NW.	34	0	10	12	7	6	0	2	3	4	0	28	2
March	58	34	46	72	19	16	3	0.71	0.32	6.9	63	36	12	301	81	3.9	7.6	NW.	36	0	17	6	8	7	0	0	2	1	0	12	0
April	66	40	53	82	28	27	20	0.20	0.13	0.9	58	27	8	283	71	5.4	7.4	SE.	37	0	9	13	8	4	0	0	1	0	0	7	0
May	73	45	59	88	9	32	15	1.05	1.04	0	43	15	5	359	81	3.8	8.9	NW.	49	1	16	10	5	3	1	1	0	0	0	0	0
June	86	57	72	94	30	43	2	T.	T.	0	30	10	5	418	94	1.7	8.4	NW.	34	0	25	5	0	0	1	0	0	0	11	0	0
July	90	64	77	98	5	57	4	0.76	0.33	0	52	28	8	333	73	4.3	8.0	SE.	37	0	9	17	5	8	11	0	0	0	16	0	0
August	84	61	72	92	1	54	31	2.16	0.75	0	62	32	10	319	75	4.0	7.6	SE.	35	0	14	13	4	8	12	0	0	0	1	0	0
September	79	52	66	88	4	42	28	0.50	0.28	0	54	24	12	318	85	2.6	7.7	SE.	37	0	19	10	1	4	3	0	0	0	0	0	0
October	63	39	51	75	6	29	19	2.12	0.52	0	78	46	23	247	71	3.4	7.1	SE.	38	0	18	7	6	11	4	0	0	0	0	8	0
November	48	23	36	69	5	6	13	0.34	0.19	4.8	72	42	22	254	84	2.6	5.9	SE.	56	1	19	8	3	2	0	0	2	2	0	26	0
December	35	14	25	55	6	0	28	0.27	0.14	5.8	84	63	32	181	62	5.4	5.8	NW.	38	0	9	14	8	8	0	0	7	15	0	30	1
Year	63	39	51	98	July 5.	−9	Feb. 1.	9.74	1.04	35.1	65	39	5	3,370	74	4.1	7.0	SE.	56	3	169	123	74	77	32	4	30	38	28	142	5

NOTE.—Precipitation includes rain and melted snow, hail, and sleet. "T." indicates trace of precipitation.

As mentioned previously and explained later, the larvæ which hatch from the eggs deposited by the second brood of moths do not transform into pupæ and moths the same season as hatched, but pass the winter in the larva stage. Hence there is, in the Grand Valley of Colorado, what might be called a "partial" or "incomplete" third generation. However, these eggs and larvæ are known as third-brood eggs and larvæ.

The "life cycle" of a generation includes the time from the deposition of the egg to the emergence of the moth of the same generation.

The "complete life cycle" extends from the time of the deposition of the egg of one generation to the deposition of the egg of the next generation and, strictly speaking, should include the female sex only.

The seasonal-history studies begin with the wintering or spring-brood larvæ which transform to pupæ of the spring brood and from which issue the moths of the spring brood.

The moths of the spring brood deposit the eggs of the first brood, which, upon hatching, are known as larvæ of the first brood. Some of these remain in the larva stage until the following spring, while the remainder transform successively into the pupæ and moths of the first brood.

The moths of the first brood produce the eggs of the second brood, which, after their incubation period, result in the larvæ of the second brood. Some of these, like some of the first-brood larvæ, are wintering individuals, while the others transform and become successively the pupæ and moths of the second brood.

The moths of the second brood deposit the eggs of the third brood. In the Grand Valley of Colorado all the larvæ of this brood pass the winter, comprising part of the spring brood of pupæ and moths the following season.

Wintering larvæ or larvæ of the spring brood (*spring-brood larvæ*) include: All of the nontransforming larvæ of the first and second broods and all of the larvæ of the third brood.

Pupæ of the spring brood (*spring brood pupæ*) include: All of the pupæ from the spring-brood larvæ.

Moths of the spring brood (*spring-brood moths*) include: All of the moths from the pupæ of the spring brood.

The first generation includes:

1. The eggs of the first brood.
2. The larvæ of the first brood:
   (*a*) Transforming first-brood larvæ;
   (*b*) Wintering first-brood larvæ.
3. The pupæ of the first brood.
4. The moths of the first brood.

The second generation includes:

1. The eggs of the second brood.
2. The larvæ of the second brood:
   (*a*) Transforming second-brood larvæ;
   (*b*) Wintering second-brood larvæ.
3. The pupæ of the second brood.
4. The moths of the second brood.

The third generation (*not complete in the Grand Valley*) includes:

1. The eggs of the third brood.
2. The larvæ of the third brood, all of which are wintering individuals.

METHODS AND REARING APPARATUS EMPLOYED IN THE LIFE-HISTORY STUDIES.

The methods used in the study of the biology of the codling moth in the Grand Valley were in most respects like those employed in similar investigations of the bureau at other places.

The rearing apparatus likewise conformed with that previously used, with the exception of an improved cocooning rack, devised by Mr. Van Leeuwen. This device was made of wooden strips 8 inches long, $1\frac{3}{4}$ inches wide, $\frac{1}{4}$ inch thick, having two rows of compartments or cells, each cell of which would accommodate one codling moth larva. These cells were covered with a strip of celluloid, through which the transformation of the insect could be observed, and the record of the observations was kept by placing a reference number at the head of each cell in the space provided for that purpose. After the inspection of the insects, the cells were covered by a strip of wood one-eighth inch in thickness, which was held in place by means of wire clamps made from paper clips. Three views of the cocooning rack are shown in Plate III: *a*, the rack with cover removed, showing the cells and larvæ within as well as the reference numbers; *b*, side view, showing cover held in place by wire clamps; *c*, top view.

The cages used in the studies usually consisted of glass battery jars, 6 by 8 inches, covered with cloth tops which are held in place by rubber bands.

The oviposition cages consisted of the regular battery jars, the bottoms of which were covered with a 2-inch layer of slightly moist sand. A fresh twig of apple or pear foliage was placed daily in each cage, as was also a small piece of sponge moistened with a solution of brown sugar.

The incubation cages, in which the eggs were kept, were similar to those used for oviposition purposes. The leaves, on which the eggs had been deposited, were held in a flat position between two pieces of wire screen for a day or more to prevent curling while they dried.

Pupation studies.—The time of pupation of the larvæ was found by a daily examination of the cocooning racks.

Studies of the pupal period.—The pupal period was determined for each individual by noting the time of pupation and emergence of the moth.

Studies of moth emergence.—The records of the emergence of moths were made daily.

Studies of the oviposition.—In order to secure data on the oviposition of the moths, it was necessary to confine the moths issuing on different days in separate cages. The foliage in these cages was removed daily and the number of eggs recorded.

Studies of the length of life of moths.—At the time of changing the foliage in the oviposition cages, all dead moths were removed. The sex was then determined and the length of life computed.

Studies of the incubation period.—The two distinct embryological stages of the eggs previous to hatching were noted, namely, (1) the "red-ring stage," or the first marked indication of the development of the circulatory system, and (2) the so-called "black-spot stage," or the initial appearance of the black head of the developing larva. (See Pl. IV, B.)

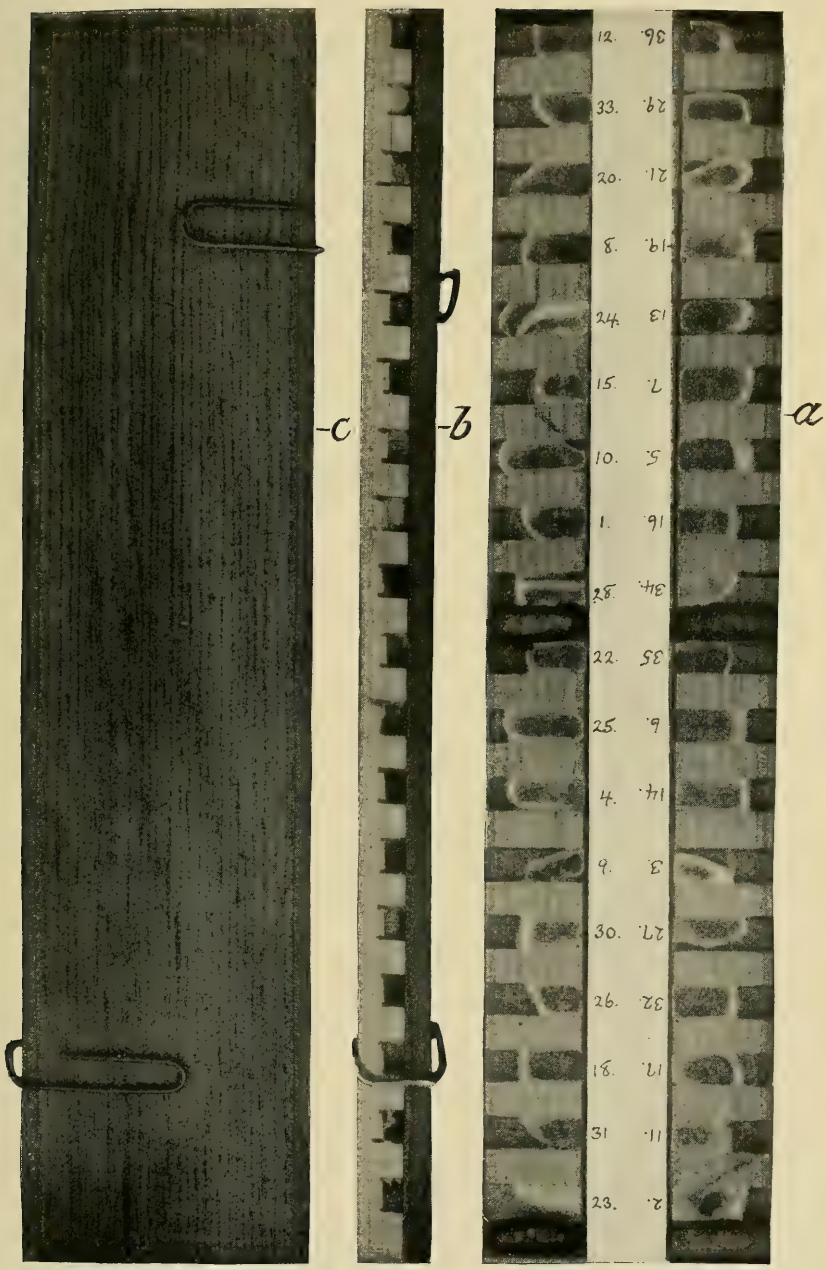
Studies of the larval feeding periods.—The feeding studies of the larvæ of the first brood were conducted in two ways: (1) By the stock-jar method and (2) by the bagged-fruit method. The feeding periods of the larvæ of the second and third broods were ascertained according to the stock-jar method only.

In the stock-jar method, apples free from codling-moth larvæ were placed in a wire basket within a battery jar into which were introduced newly-hatched larvæ. These soon entered the apples and completed their feeding period within the fruit. Cocooning racks were placed in each jar and these were examined daily to ascertain when the larvæ left the fruit, and from these data the length of the feeding period was computed.

The bagged-fruit method consisted in placing newly-hatched larvæ on apples developing on the tree and covering the fruit with finely perforated paper bags. The fruit selected was first carefully examined to insure its freedom from previous infestation. The inclosed fruit was allowed to remain on the tree for a period of two weeks, after which it was removed and kept at the insectary under conditions identical with those described for the stock-jar method.

THE INSECTARY.

Most of the life-history studies of the codling moth were made at the insectary, a partial interior view of which is shown in Plate V. This was located to the rear of the laboratory and was partially

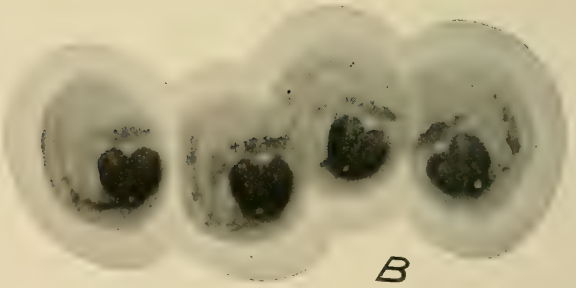


THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

Three views of cocooning rack: *a*, With cover removed to show the cocooning cells; *b*, side view; *c*, top view.

A. EGG.

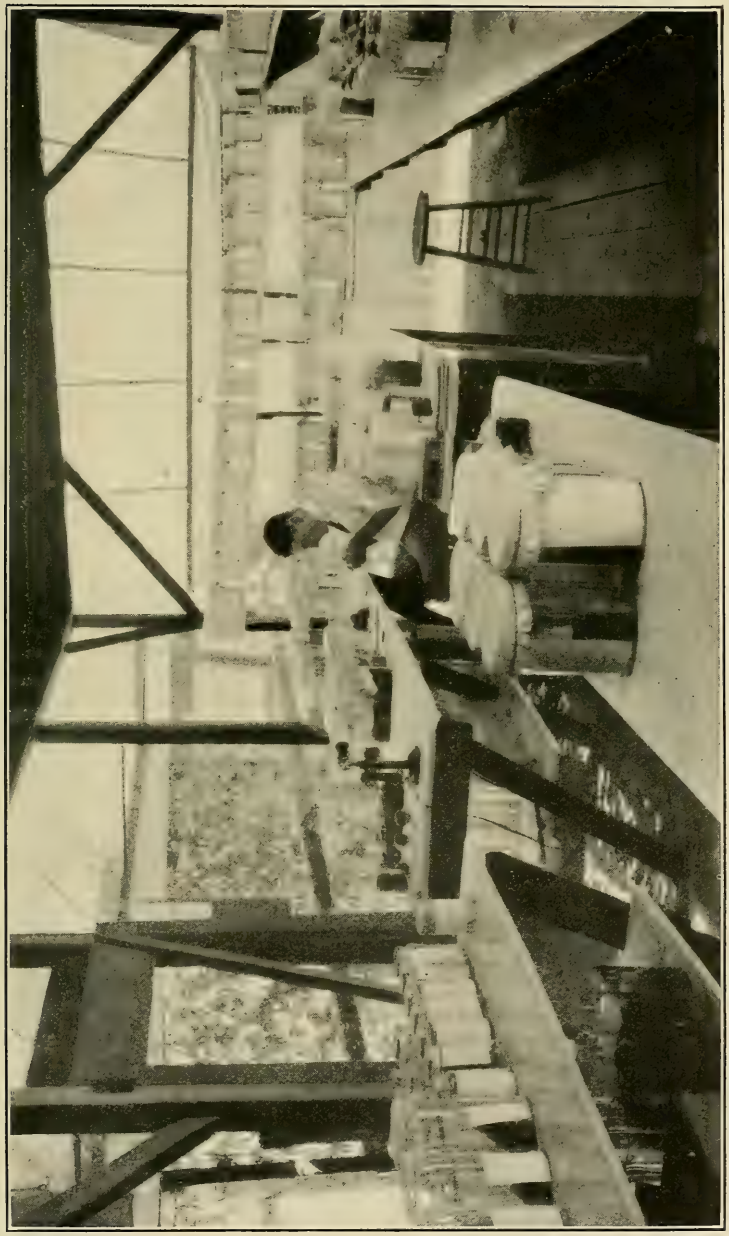
Greatly enlarged.



B. EGGS IN ADVANCED BLACK-SPOT STAGE ALMOST READY TO HATCH.

Greatly enlarged.

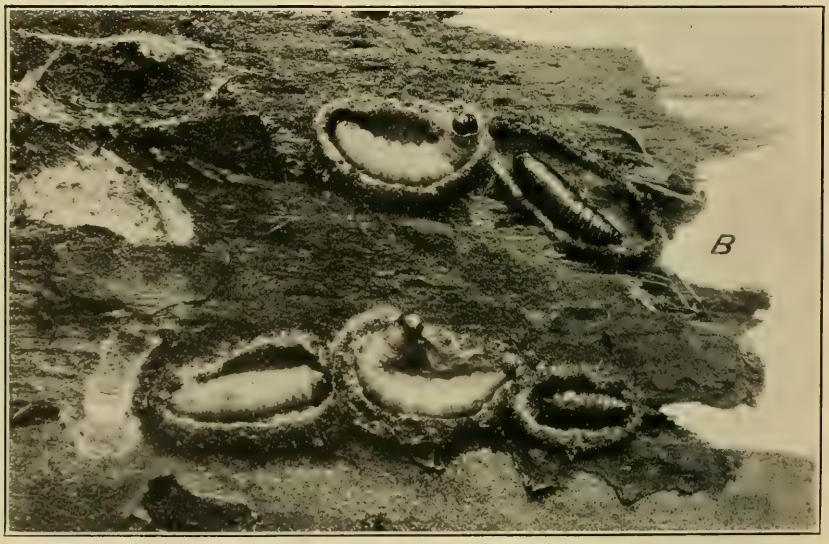
THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.



THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

Interior view of insectary.

A. APPLES INFESTED WITH LARVÆ.



B. LARVÆ AND PUPÆ IN COCOONS.

THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

shaded by trees, vines, awnings, and other buildings. As will be noted in the photograph, the insectary was of open-type construction, permitting free circulation of the air; it was 40 feet long and 11 feet wide, with the lowest part of the roof 11 feet in elevation. The temperature conditions within the insectary closely paralleled those in the orchards, as was determined by frequent observations. A thermograph and maximum and minimum thermometers were kept in the insectary for temperature records; and the average daily temperatures used in the various graphs and charts throughout this publication were computed for each day by adding the temperature recorded by this thermograph for each hour of that day and dividing the sum by 24. Other data pertaining to weather conditions were obtained through the courtesy of the local station of the United States Weather Bureau, which was located within a half mile of the insectary.

SEASONAL-HISTORY STUDIES OF 1915.

The seasonal-history studies of the codling moth were commenced in 1915 with the observations of the time of pupation of the spring-brood larvæ.[1] The climate throughout the season was generally normal, except in early May, when subnormal temperatures which fell below the freezing point occurred successively on the mornings of May 1 to 4 inclusive and again on May 7. On the 2d of May the temperature dropped to 22° or 23° F. in many sections of the valley, one exception being the Palisade peach district, which is usually favored with higher minimum temperatures. At the time of the freezes most apples had just dropped their blossoms, except the late-blooming varieties, as Rome Beauty and Jeniton.

As a result of the low temperatures, the apple crop in the Grand Valley, with the exception of that included in the Palisade district and in a few orchards where oil heaters were employed, was practically destroyed. Here and there were to be found a few pears, the blossoms of which seemingly were not so readily destroyed by the freezes as were those of the apple. The general shortage of the apple crop, however, did not in any way interfere with the life-history studies, since sufficient fruit was at hand for feeding and other purposes.

In referring to the tables the reader should bear in mind that each table is a unit in itself. Successive tables are not necessarily continuations of the life history of all of the individuals given in the previous table. For example, it will be noted that Table III is the record of the time of pupation of 320 wintering larvæ and that Table IV includes observations on the length of the pupal stage of only 233 of these individuals. Differences of this character may be due to

[1] These larvæ were collected from banded apple trees in the fall of 1914 by Mr. R. J. Fiske, of the Bureau of Entomology.

natural or artificial causes, such as death, accidental injury, parasites, the removal of specimens for other purposes, etc.

WINTERING LARVÆ.

As previously stated (p. 6), the wintering larvæ consist of all of the nontransforming larvæ of the first and second broods and all of the larvæ of the third brood. (See Plate VI, B.)

The winter cocoon.—The winter cocoon is a small, well-built structure, having heavy silk walls in which are frequently interwoven small particles of bark. When compared with the more hastily constructed summer cocoon, it will be noted that the winter cocoon is of heavier construction and thus affords the larva protection against the low temperatures of the winter season. The cocoon is generally more or less oval in form, but varies to conform with the space in which it is built. The winter cocoon is usually found beneath the bark on the trunk of the tree, well concealed from birds and insect enemies, in the crotches of the larger limbs, or in decayed or partially decayed tree cavities, etc. Not infrequently, in the Grand Valley, a mass of 10 to 20 cocoons, side by side or partially on top of one another, may be found on the tree in places particularly favorable for hibernation. The cocoons are occasionally to be found around the base of the tree just below the surface soil or within cracks in the soil. Again, a considerable number of winter cocoons are constructed in various cracks and crevices within packing houses and storage cellars where the harvested fruit has been kept.

Remodeling of the cocoon.—The wintering larva begins activity during the first warm days of spring; it then remodels its cocoon by attaching thereto a slender silken exit tube which provides for the safe issuance of the moth. This tube is usually a fraction of an inch in length, although tubes have been found that were 2 or more inches long, depending upon the location of the cocoon. Upon the completion of the exit tube a lightly constructed silken partition, which serves to separate the tube from the cocoon proper, is frequently built at its base.

Emergence of the moth.—Shortly before the time the moth emerges, the pupa punctures this silken partition and, by means of its retrose spines, wriggles its way to the end of the exit tube. The moth then ruptures the pupal skin, crawls into clear space, spreads and dries its wings, and in due course of time takes flight. Were it not for the exit tube, many moths would be unable to free themselves from the place in which the larvæ have cocooned.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—Observations of the time of pupation of the wintering larvæ were made daily by examination of the larvæ within the cocooning racks. The tabulated results showing the time of

pupation of 320 larvæ are given in Table III and illustrated in figure 1.

It will be noted that the earliest pupation occurred April 14, when two larvæ transformed, and that the last of the wintering larvæ pupated June 8 or approximately 8 weeks later. On April 26 there was a marked increase in the rate of pupation and a still greater increase two days later, owing to higher temperatures, as shown in figure 1. Following this activity the temperatures became abnormally low, reaching in the insectary a minimum of 27° F. on May 2, on this date only one larva pupating. This freeze contributed largely to the destruction of practically the entire fruit crop of the Grand Valley west of the Palisade district. Freezing temperatures recurred on the mornings of May 3, 4, and 7, but on the latter date the temperature reached a maximum of 70° F., and, as a result, 18 larvæ pupated. Pupation thereafter continued quite regularly (except on May 10) and reached its maximum on May 12. During the period of one week, May 7 to 13, inclusive, approximately 40 per cent of the wintering larvæ pupated. Following this crest of activity the rate of pupation gradually diminished in the normal way.

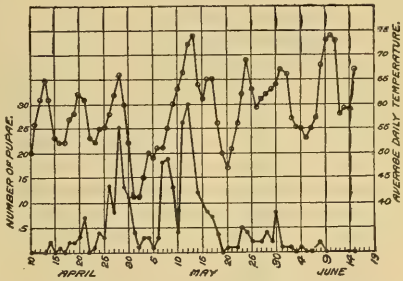


FIG. 1.—Time of pupation of spring-brood pupæ of the codling moth, Grand Junction, Colo., 1915.

TABLE III.—*Time of pupation of wintering larvæ of the codling moth, Grand Junction, Colo., 1915.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
Apr. 14	2	Apr. 26	13	May 8	19	May 20	1	June 1	1
15	0	27	8	9	13	21	1	2	1
16	1	28	25	10	4	22	1	3	0
17	0	29	13	11	26	23	5	4	1
18	2	30	11	12	30	24	4	5	0
19	2	May 1	4	13	20	25	2	6	0
20	3	2	1	14	12	26	2	7	1
21	7	3	3	15	10	27	2	8	2
22	0	4	3	16	8	28	4		
23	1	5	1	17	7	29	2	Total...	320
24	4	6	3	18	4	30	8		
25	3	7	18	19	0	31	1		

Length of the pupal stage.—In Table IV will be found the length of the pupal stage of 233 pupæ of the spring brood. Reference to this table will show that the first pupation occurred April 14 and the last June 7. The pupal period of the individuals that pupated early in the season was naturally longer, owing to the lower average

temperatures, than was the pupal period of those insects that transformed later in the spring. The average length of the pupal stage was 27.58 days, the maximum 34 days, and the minimum 15 days.

TABLE IV.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Grand Junction, Colo., 1915.*

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.														
		15	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Apr. 14	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
16	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
18	2	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....
19	2	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1
20	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
21	7	....	....	....	....	....	....	....	....	....	....	....	....	1	5	1
23	1	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
24	3										1	2	....	....	....	....
25	2	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....
26	10	....	....	....	....	....	....	....	....	....	6	1	3	....	....	....
27	7	....	....	....	....	....	....	....	....	....	....	3	3	1	....	....
28	18	....	....	....	....	....	....	....	....	....	2	6	4	6	....	....
29	10	....	....	....	....	....	....	....	....	....	....	2	6	2	....	....
30	8	....	....	....	....	....	....	....	....	1	....	4	3	....	....	....
May 1	3	....	....	....	....	....	....	....	....	....	2	1				
3	3	....	....	....	....	....	....	....	2	....	1	....	....	....	....	....
4	3	....	....	....	....	....	....	....	1	2	....	....	....	....	....	....
5	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....
6	3	....	....	....	....	1	2	....	....	....	....	....	....	....	....	....
7	15	....	....	....	....	4	11	....	....	....	....	....	....	....	....	....
8	15	....	....	1	1	10	....	2	....	1	....	....	....	....	....	....
9	7	....	....	....	3	1	3	....	....	....	....	....	....	....	....	....
10	2	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....
11	21	....	1	....	1	....	1	....	5	8	4	....	1	....	....	....
12	20	....	....	....	....	....	....	2	6	10	2	....	....	....	....	....
13	17	....	....	....	....	....	....	....	3	12	2	....	....	....	....	....
14	10	....	....	....	....	....	....	....	7	1	1	....	1	....	....	....
15	6	....	....	....	....	....	....	....	3	3	....	....	....	....	....	....
16	3	....	....	....	....	....	....	....	2	....	1	....	....	....	....	....
17	6	....	....	....	....	1	1	1	....	1	2	....	....	....	....	....
18	4	....	....	....	....	....	1	....	3	....	....	....	....	....	....	....
21	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....
22	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....
23	3	....	....	1	1	1	....	....	....	....	....	....	....	....	....	....
24	2	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....
25	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
26	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....
27	2	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....
28	2	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....
30	6	....	6	....	....	....	....	....	....	....	....	....	....	....	....	....
June 7	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	233	1	7	6	9	22	19	7	32	39	25	21	23	13	5	4

	Days.
Average length of pupal stage	27.58
Maximum length of pupal stage	34
Minimum length of pupal stage	15

MOTHS OF THE SPRING BROOD.

Time of emergence.—The tabulated data of the emergence of 1,539 moths of the spring brood are given in Table V. It will be noted in this table that the first moths issued May 12, while the last moth of this brood did not emerge until June 29 or nearly seven weeks later. The emergence is largely dependent upon temperature and atmospheric conditions and hence the number of moths issuing daily fluctuates more or less in accordance with the climatic factors. The number of moths appearing daily gradually increased (with

one exception) up to May 17, as shown diagrammatically in figure 2, and probably would have continued growing larger had it not been for the retarding influence of the weather, which began May 18 and continued to May 21, inclusive. The temperature dropped considerably on May 18 and was accompanied by 0.12 inch of precipitation.

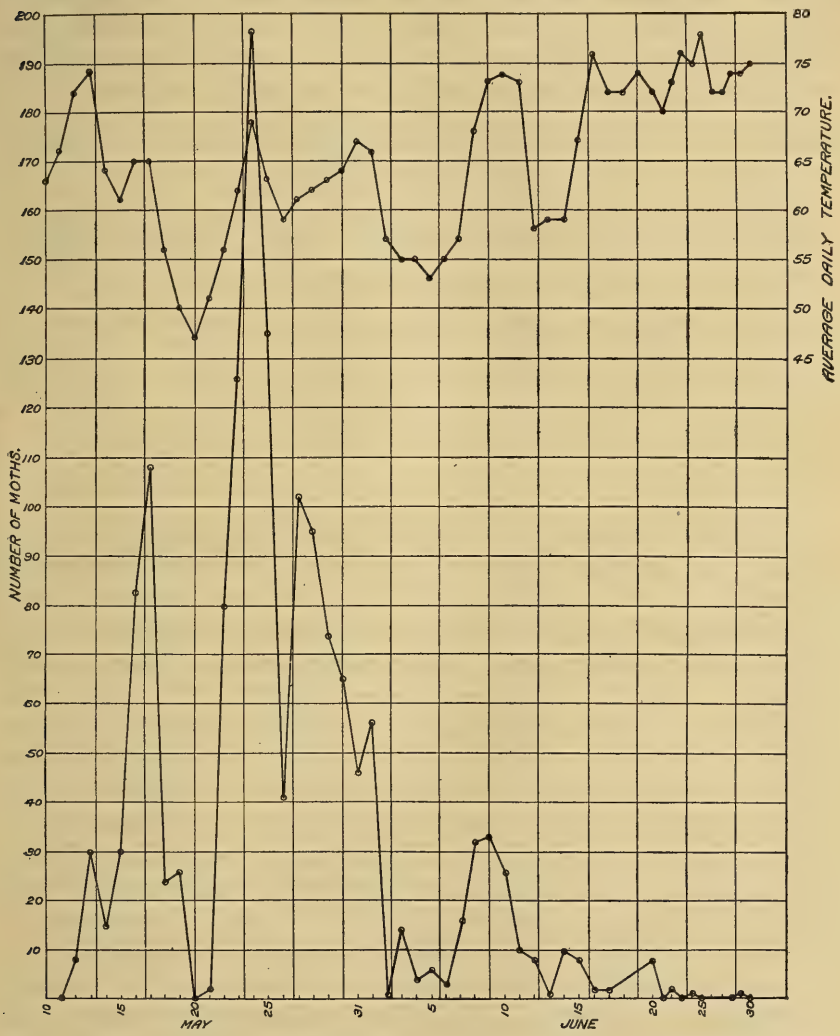


FIG. 2.—Time of emergence of moths of the spring brood of the codling moth, Grand Junction, Colo., 1915.

On the following day, May 19, the temperature dropped somewhat lower and heavy rains (0.44 inch) occurred in the afternoon and evening. The next day, May 20, was colder than the two preceding days, the maximum temperature being 58° F. and the minimum 44° F. In addition to the low temperature, it rained practically the en-

tire day, with a total of 0.29 inch of precipitation. The development and activity of the codling moth were almost completely arrested, with the result that no moths issued and no eggs were deposited. With normal temperature conditions on May 18, 19, and 20, the emergence of moths would doubtless have been large. The weather turned increasingly warmer May 22, 23, and 24, and on the latter date the maximum number of moths (196) issued. Thereafter the emergence gradually decreased, the rate conforming closely to the variations of the temperature until all of the moths had issued.

TABLE V.—*Time of emergence of codling moths of the spring brood, Grand Junction, Colo., 1915.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
May 12	8	May 23	126	June 2	1	June 12	8	June 22	2
13	30	24	196	3	14	13	1	23	0
14	15	25	135	4	4	14	10	24	1
15	30	26	41	5	6	15	8	25	0
16	83	27	102	6	3	16	2	26	0
17	108	28	95	7	15	17	2	27	0
18	24	29	74	8	32	18	4	28	0
19	26	30	65	9	33	19	6	29	1
20	0	31	46	10	26	20	8		
21	2	June 1	56	11	10	21	0	Total...	1,539
22	80								

Oviposition by moths of the spring brood.—In Table VI are recorded the observations of the oviposition of 1,140 female moths confined with 1,007 male moths in 92 cages. In this connection it is of interest to note the variations in the time of oviposition by the moths in the several cages. Thus, moths emerging May 12 and confined in cage 1 did not deposit eggs until May 22, whereas the moths in cage 2, although issuing a day later, commenced oviposition May 15. A more detailed study of the table will show numerous variations of the oviposition habits of the moths. A summary of the data is as follows: The number of days before oviposition averaged 6.19, the maximum was 19, and the minimum 2; the number of days for the period of oviposition averaged 13.82, maximum 33, minimum 1; the average number of days from the date of emergence to the date of last oviposition was 19.14, maximum 37, minimum 5.

Number of eggs per female moth.—It was found in the oviposition studies of the moths of the spring brood that the average number of eggs deposited was 12.59 per female moth. This number was obtained by dividing the total number of eggs deposited by the total number of female moths caged, as shown in Table VI.

TABLE VI.—*Oviposition of codling moths of the spring brood in rearing cages, Grand Junction, Colo., 1915.*

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male.	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition period.	From date of emergence to last oviposition.
1	29	15	14	May 12	May 22	June 1	82	10	11	20
2	20	6	14	May 13	May 15	June 9	230	2	26	27
3	24	11	13	...do.....	May 24	June 3	162	11	11	21
4	28	12	16	May 14	May 17	May 31	207	3	15	17
5	25	12	13	May 15	May 18	June 15	231	3	29	31
6	25	9	16	May 16	...do.....	June 11	346	2	25	26
7	25	11	14	...do.....	May 21	June 22	508	5	33	37
8	24	12	12	...do.....	May 22	June 7	70	6	17	22
9	19	6	13	...do.....	May 23	June 4	94	7	13	19
10	23	7	16	...do.....	May 28	June 2	2	12	6	17
11	34	14	20	May 17	May 22	June 14	222	5	24	28
12	23	10	13	...do.....	May 24	June 1	115	7	9	15
13	22	15	7	...do.....	...do.....	June 11	162	7	19	25
14	27	16	11	...do.....	...do.....	June 15	271	7	23	29
15	25	16	9	May 18	May 25	June 13	151	7	20	26
16	28	19	9	May 19	...do.....	June 17	80	6	24	29
17	8	5	3	May 21	June 9	June 10	83	19	2	20
18	22	7	15	May 22	May 24	June 14	299	2	22	23
19	25	13	12	...do.....	May 25	June 11	204	3	18	20
20	27	15	12	...do.....	...do.....	...do.....	77	3	18	20
21	16	5	11	...do.....	May 29	June 9	130	7	12	18
22	21	10	11	May 23	May 25	June 15	74	2	22	23
23	25	14	11	...do.....	...do.....	June 17	149	2	24	25
24	23	8	15	...do.....	May 27	June 8	85	4	13	16
25	21	7	14	...do.....	May 31	June 17	132	8	18	25
26	12	7	5	...do.....	June 9	June 23	5	17	15	31
27	24	15	9	May 24	May 27	June 19	216	3	24	26
28	28	13	15	...do.....	May 31	June 20	176	7	21	27
29	23	12	11	...do.....	June 1	June 8	78	8	8	15
30	24	10	14	...do.....	...do.....	June 11	88	8	11	18
31	20	8	12	...do.....	...do.....	June 19	98	8	19	26
32	26	10	16	...do.....	...do.....	June 25	28	8	25	32
33	26	15	11	...do.....	June 3	June 23	451	10	21	30
34	23	8	15	...do.....	June 6	June 19	226	13	14	26
35	24	15	9	May 25	May 28	June 18	200	3	22	24
36	24	10	14	...do.....	May 30	June 17	284	5	19	23
37	21	9	12	...do.....	June 1	June 19	53	7	19	25
38	23	13	10	...do.....	June 9	June 15	21	15	7	21
39	22	9	13	May 26	May 31	June 19	413	5	20	24
40	20	9	11	...do.....	...do.....	...do.....	419	5	20	24
41	30	12	18	May 27	June 1	...do.....	100	5	19	23
42	25	13	12	...do.....	...do.....	June 6	52	5	6	10
43	21	9	12	...do.....	...do.....	June 18	244	5	18	22
44	22	12	10	...do.....	May 31	June 16	204	4	17	20
45	24	14	10	May 28	June 1	...do.....	189	4	16	19
46	24	10	14	...do.....	...do.....	...do.....	243	4	16	19
47	22	7	15	...do.....	...do.....	June 19	333	4	19	22
48	22	7	15	...do.....	...do.....	June 26	235	4	26	29
49	25	8	17	May 29	June 2	June 18	323	4	17	20
50	31	14	17	...do.....	...do.....	June 28	457	4	27	30
51	21	8	13	...do.....	June 4	June 16	138	6	13	18
52	19	11	8	...do.....	June 7	...do.....	92	9	10	18
53	23	15	8	...do.....	June 10	June 11	39	12	2	13
54	20	9	11	May 30	June 4	June 19	221	5	16	20
55	26	8	18	...do.....	...do.....	June 22	296	5	19	23
56	25	14	11	...do.....	June 7	June 17	157	8	11	18
57	23	14	9	...do.....	June 9	June 22	126	10	14	23
58	23	15	8	May 31	June 7	June 7	5	7	1	7
59	20	11	9	...do.....	...do.....	June 17	117	7	11	17
60	26	10	16	...do.....	June 9	June 14	67	9	6	14
61	21	10	11	...do.....	...do.....	...do.....	51	9	6	14
62	24	14	10	June 1	June 7	June 16	111	6	10	15
63	22	13	9	...do.....	June 10	June 19	94	9	10	18
64	27	12	15	...do.....	...do.....	...do.....	113	9	10	18
65	11	3	8	June 2	June 11	June 12	54	9	2	10
66	23	11	12	June 3	June 9	June 16	183	6	8	13
67	11	7	4	June 4	June 10	June 11	49	6	2	7
68	6	4	2	June 5	June 11	June 22	82	6	12	17
69	19	9	10	June 6	...do.....	June 21	28	5	11	15

TABLE VI.—*Oviposition of codling moths of the spring brood in rearing cages, Grand Junction, Colo., 1915*—Continued.

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male.	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition period.	From date of emergence to last oviposition.
70	23	10	13	June 7	June 11	June 20	251	4	10	13
71	25	15	10	...do.....	June 16	June 16	3	9	1	9
72	27	15	12	June 8	June 11	June 27	250	3	7	19
73	22	13	9	...do.....	June 18	June 21	10	10	4	13
74	22	7	15	...do.....	June 21	June 25	7	13	5	17
75	31	18	13	June 9	June 16	June 26	238	7	11	17
76	29	12	17	...do.....	...do.....	June 27	52	7	12	18
77	33	13	20	June 10	June 12	June 23	211	2	12	13
78	31	21	10	...do.....	...do.....	June 26	100	2	15	16
79	31	18	13	...do.....	June 15	June 25	367	5	11	15
80	38	16	22	June 11	June 16	...do.....	134	5	10	14
81	29	14	15	June 12	...do.....	June 23	275	4	8	11
82	9	1	8	June 13	June 19	June 21	7	6	3	8
83	20	10	10	June 14	.....	.....	[1] 1	.....	.....	.....
84	30	13	17	June 15	June 18	June 29	54	3	12	14
85	32	11	21	June 16	June 19	June 26	129	3	8	10
86	30	13	17	June 17	...do.....	July 3	293	2	15	16
87	25	7	18	June 18	June 22	June 30	92	4	9	12
88	25	10	15	...do.....	June 23	July 1	202	5	9	13
89	24	10	14	June 19	June 24	July 4	152	5	11	15
90	25	11	14	June 20	June 22	July 1	182	2	10	11
91	12	4	8	June 21	.....	.....	0	.....	.....	.....
92	9	3	6	June 22	June 27	June 27	24	5	1	5
Average							.....	6.19	13.82	19.14
Maximum							.....	19	33	37
Minimum							.....	2	1	5

[1] Deposited on side of cage.

Number of male moths	1,007
Number of female moths	1,140
Total number of moths	2,147
Total number of eggs	14,359
Average number of eggs per female moth	12.59

Length of life of moths.—The dead moths in the oviposition cages were removed each day; their sex was then determined and the length of their life computed. The results of these observations are given in Table VII, in which it will be found that the average length of life of 1,283 male moths was 14.59 days and of 1,462 female moths 15.86 days; the maximum length of life of the male moths was 36 days, of the female moths 39 days; the minimum length of life of the male moths was 1 day, of the female moths 1 day.

TABLE VII.—*Length of life of male and female codling moths of the spring brood in captivity: Summary of records of 2,745 individual moths, Grand Junction, Colo., 1915.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	9	1	5	15	61	15	95	29	8	29	15
2	9	2	3	16	58	16	99	30	11	30	6
3	4	3	5	17	58	17	88	31	4	31	4
4	14	4	11	18	50	18	73	32	6	32	5
5	29	5	12	19	41	19	72	33	5	33	10
6	46	6	18	20	65	20	91	34	3	34	2
7	63	7	41	21	43	21	69	35	2	35	3
8	79	8	39	22	38	22	36	36	1	36	0
9	49	9	72	23	26	23	37	37	0	37	0
10	77	10	77	24	27	24	33	38	0	38	1
11	65	11	79	25	21	25	28	39	0	39	1
12	71	12	88	26	25	26	24				
13	99	13	97	27	10	27	14	Total.	1,283	Total.	1,462
14	79	14	98	28	17	28	11				

Average length of life of male moths, 14.59 days; female moths, 15.86 days.
Maximum length of life, male moths, 36 days; female moths, 39 days.
Minimum length of life of male moths, 1 day; female moths, 1 day.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—The first eggs of this brood were deposited on May 13 in a cage in which were confined some of the earliest moths of the spring brood, emerging on different dates. The deposition of the eggs, as shown in Table VIII, continued daily

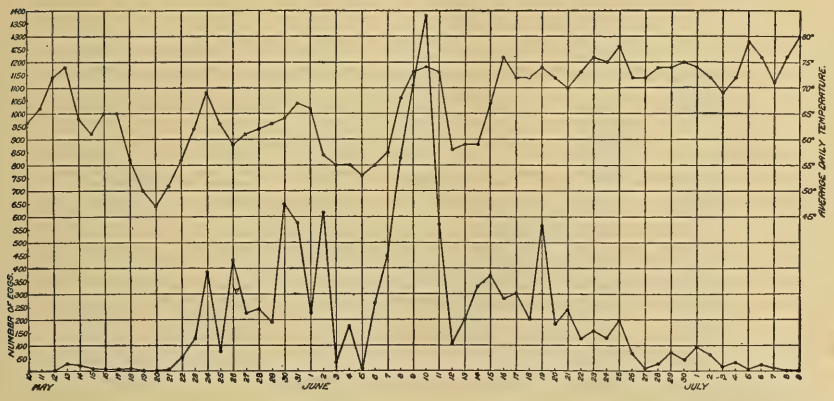


FIG. 3.—Time of deposition of eggs of the first brood of the codling moth, Grand Junction, Colo., 1915.

up to and including July 8, with the exception of May 19 and 20, on which days no eggs were laid owing to the unfavorable weather conditions previously mentioned (see p. 13). The greatest number of eggs deposited on any one day was 1,379, as will be noted in the

graph, figure 3. By further reference to this figure it will be seen that the average daily temperatures from June 3 to June 7 were relatively low and that during this period the moths did not deposit very freely. With the rise in temperature from June 7 to 10, the moths were much more active and deposited 828 eggs on June 8, 1,106 eggs on June 9, and the maximum number of eggs, 1,379, on June 10. The average temperature was also high on June 11, but the deposition of eggs was notably less than on the preceding days. Following the crest of egg deposition, the number daily deposited gradually diminished, except on June 19, when 564 eggs were laid.

TABLE VIII.—*Time of deposition, length of incubation, and time of hatching of eggs of the first brood of the codling moth, Grand Junction, Colo., 1915.*

Observation.	Number of eggs.	Date—				Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.	
						Days.	*Days.*	*Days.*
1	15	May 13	May 16	May 25	May 27	3	12	14
2	10	...do			May 28			15
3	2	May 14	May 16	May 27	...do	2	13	14
4	20	...do			May 29			15
5	5	May 15	May 17	May 28	...do	2	13	14
6	1	...do			May 30			15
7	4	May 16	May 22	May 29	...do	6	13	14
8	2	...do			May 31			15
9	1	May 17	May 23	May 30	...do	6	13	14
10	5	...do			June 1			15
11	8	May 18	May 27	May 31	...do	9	13	14
12	2	...do			June 2			15
13	5	May 21	May 27	May 31	June 1	6	10	11
14	39	May 22	May 28	...do	June 2	6	9	11
15	12	...do			June 3			12
16	1	...do			June 4			13
17	1	...do			June 5			14
18	45	May 23	May 28	June 1	June 2	5	9	10
19	22	...do			June 3			11
20	34	...do			June 4			12
21	14	...do			June 5			13
22	3	...do			June 6			14
23	7	...do			June 7			15
24	20	May 24	May 29	June 1	June 4	5	8	11
25	136	...do			June 5			12
26	140	...do			June 6			13
27	65	...do			June 7			14
28	19	May 25	May 29	June 4	...do	4	10	13
29	42	...do			June 8			14
30	8	...do			June 9			15
31	284	May 26	May 30	June 4	June 8	4	9	13
32	90	...do			June 9			14
33	2	May 27	May 31	June 7	June 8	4	11	12
34	187	...do			June 9			13
35	157	May 28	May 31	June 7	...do	3	10	12
36	41	...do			June 10			13
37	5	...do			June 11			14
38	120	May 29	June 1	June 8	June 10	3	10	12
39	51	...do			June 11			13
40	162	May 30	June 3	June 9	June 10	4	10	11
41	299	...do			June 11			12
42	19	...do			June 12			13
43	367	May 31	June 3	June 10	June 11	3	10	11
44	57	...do			June 12			12
45	11	...do			June 13			13
46	7	June 1	June 4	June 10	June 12	3	9	11
47	161	...do			June 13			12
48	2	...do			June 14			13
49	324	June 2	June 8	June 11	June 13	6	9	11
50	43	...do			June 14			12
51	30	...do			June 15			13
52	6	June 3		June 11	June 14		8	11
53	29	...do			June 15			12

TABLE VIII.—*Time of deposition, length of incubation, and time of hatching of eggs of the first brood of the codling moth, Grand Junction, Colo., 1915*—Con.

Observation.	Number of eggs.	Date—				Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.	
						Days.	*Days.*	*Days.*
54	46	June 4	June 9	June 11	June 14	5	7	10
55	81	...do			June 15	3		11
56	4	June 5		June 13	June 15		8	10
57	1	...do			June 16			11
58	1	...do			June 17			12
59	163	June 6	June 10	June 12	June 15	4	6	9
60	55	...do			June 16			10
61	49	June 7	June 10	June 12	June 15	3	5	8
62	284	...do			June 15			9
63	215	June 8	June 10	June 14	June 17	2	6	9
64	191	...do			June 18			10
65	619	June 9	June 11	June 16	June 17	2	7	8
66	55	June 10	June 12	...do	June 17	2	6	7
67	690	...do			June 18	2	6	8
68	69	...do			June 19			9
69	233	June 11	June 15	June 18	...do	4	7	8
70	85	...do			June 20			9
71	76	June 12	June 16	June 18	...do	4	6	8
72	12	...do			June 21			9
73	102	June 13	June 16	June 19	June 20	3	6	7
74	69	...do			June 21			8
75	241	June 14	June 17	June 19	...do	3	5	7
76	56	...do			June 22			8
77	237	June 15	June 17	June 20	...do	2	5	7
78	11	...do			June 23			8
79	245	June 16	June 18	June 21	...do	2	5	7
80	20	...do			June 24			8
81	248	June 17	June 19	June 22	June 23	2	5	6
82	12	...do			June 24			7
83	141	June 18	June 21	June 24	June 25	3	6	7
84	49	...do			June 25			8
85	502	June 19	June 21	June 24	...do	2	5	7
86	149	June 20	June 22	June 25	...do	2	5	6
87	25	...do			June 27			7
88	198	June 21	June 22	June 28	June 28	1	5	7
89	31	...do			June 29			8
90	117	June 22	June 23	June 27	June 28	1	5	6
91	5	...do			June 29			7
92	145	June 23	June 24	June 28	June 30	1	5	7
93	3	...do			July 1			8
94	13	June 24	June 25	June 29	June 30	1	5	6
95	111	...do			July 1			7
96	191	June 25	June 26	June 30	July 2	1	5	7
97	2	...do			July 3			8
98	65	June 26	June 28	July 1	...do	2	5	7
99	4	...do			July 4			8
100	11	June 27	June 29	July 2	...do	2	5	7
101	27	June 28	June 30	July 3	...do	2	5	6
102	1	...do			July 5			7
103	74	June 29	July 1	July 3	...do	2	4	6
104	35	June 30	July 2	July 4	July 6	2	4	6
105	7	...do			July 7			7
106	94	July 1	July 2	July 6	July 8	1	5	7
107	63	July 2	July 4	July 7	July 9	2	5	7
108	1	...do			July 10			8
109	16	July 3	July 6	July 8	July 10	3	5	7
110	33	July 4	...do	July 10	July 11	2	6	7
111	1	...do			July 12			8
112	[1] 7	July 5	...do	July 11		1	6	
113	24	July 6	July 8	July 12	July 13	2	6	7
114	[1] 11	July 7	...do			1		
115	[1] 1	July 8						
	Ave.					2.70	6.62	9.14
	Max.					9	13	15
	Min.					1	4	6

[1] Eggs not included in averages due to failure to develop fully.

Length of incubation.—As will be noted in Table VIII, the earliest eggs required an incubation period about twice as long as those deposited later. This is accounted for by the lower temperatures to which the earlier eggs were subjected. The incubation period gradually decreased as the daily temperatures became higher with the advance of the season. The average number of days from the date of deposition to the time of the appearance of the red ring was 2.70, maximum 9 days, minimum 1 day; the average number of days from the date of deposition to the black-spot stage was 6.62, maximum 13 days, minimum 4 days; the average incubation period was 9.14 days, maximum 15 days, minimum 6 days.

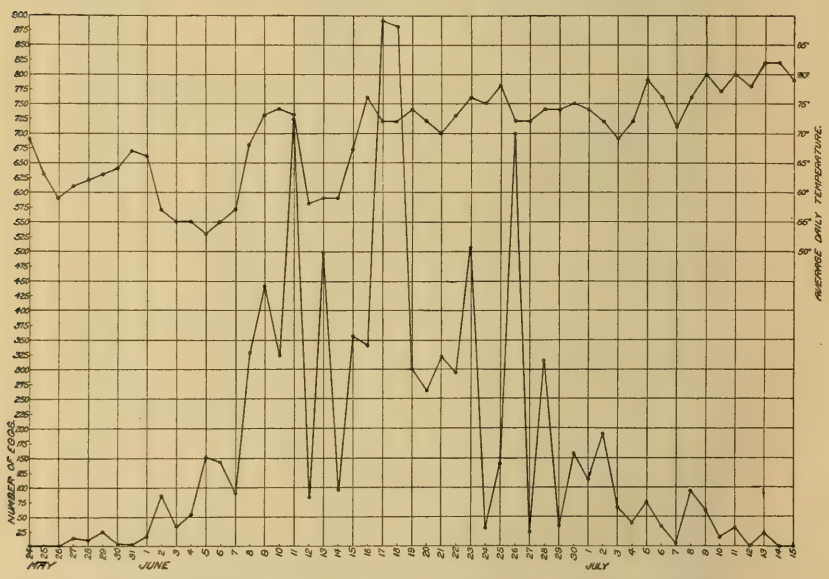


FIG. 4.—Time of hatching of eggs of the first brood of the codling moth, Grand Junction, Colo., 1915.

LARVÆ OF THE FIRST BROOD.

Time of hatching.—Larvæ of the first brood commenced to hatch on May 27 and continued to hatch until July 13, as given in the complete hatching data in Table VIII. The eggs were hatching in maximum numbers on June 17, just one week after the time when the greatest number of eggs was deposited. The interval from the date of the appearance of the first larva to the time of hatching of the larvæ in maximum numbers was 21 days. This interval would probably have been reduced somewhat had the weather been warmer on June 12, 13, and 14. The time of hatching of the eggs of the first brood is presented graphically in figure 4.

Length of the feeding period, stock-jar method.—The length of the feeding period of 758 larvæ of the first brood (both transforming

and nontransforming) according to the stock-jar method (see p. 8) is given in Table IX. As will be observed, the length of the feeding period averaged 21.64 days, maximum 35 days, minimum 12 days.

Length of the feeding period, bagged-fruit method.—In Table X will be found the results of the observations of the feeding period of 242 larvæ of the first brood (both transforming and nontransforming) by means of the bagged-fruit method (see p. 8). The average period of feeding was 22.77 days, maximum 35 days, minimum 15 days.

TABLE IX.—*Length of feeding period of larvæ of the first brood of the codling moth, stock-jar method, Grand Junction, Colo., 1915.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																							
		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
May 27	1																1								
29	2												2												
30	1													1											
June 5	5										1	1	3												
6	16								1	4	6	1	1	1	2										
7	3									2										1					
8	4								2		2														
9	9							1	3	4			1												
10	19						1	2	3	1	6	4	1						1						
11	39						1		5	6	7	7	2	3	4	2	1			1					
12	6							1	1		1	2					1								
13	9							1	2	1	2		1	1	1										
14	27					1	1	5	2	4	2	3	4	1	2	2									
15	59	1	1	1		5	11	5	3	6	11	3	4	3	1	1	1			1			1		
16	41					2	1	4	2	3	4	6	5	2	2	4		4	1			1			
17	52				1	1	1	8	9	5	6	4		7	2	6	1					1			
18	68				1	2	1	7	7	7	9	10	3	9	2	2	5		2			1			
19	56					1			8	6	9	9	6	3		4	1			3					
20	25						2	1		3	4	2	5	2	2		1	1	1			1			
21	29							1	4	5	5			5		2	5		1						1
22	18						1	2		4	1	1	1	1	2			2	1		1			1	
23	23							2	3	3		4	5	2	2		1	1							
24	24							2	4	1		2	5	2		1	2	2		2		1			
25	13						2	2	2		2		2		1		1							1	
26	24						1	3	5			5		4	2		2		2						
27	24						2		1	5	4		4		1	1	1		2		2				1
28	34					1	2	1	4		2	5	4	4		5		1			2		3		
29	15				2			5	3		3			1					1						
30	10						1	2	2	2	2					1									
July 1	12					1	4			1	1	1			4										
2	18					2	1	6	1	1	3				3						1				
3	13					3	2	1	2	1			4												
4	2						1	1																	
5	8					1		1	2	2			1		1										
6	9					1	2	1	2			2		1											
7	6	1					1	1	1				1	1											
8	17					3	1		2	3		1		3		1		2					1		
9	14				1		2	1	2	3			2				3								
10	3				1			1					1												
11	3					1			1		1														
12	2						2																		
13	1							1																	
	758	1	1	1	7	25	44	69	89	83	94	73	68	57	34	32	27	13	12	8	6	5	5	2	2

	Days.
Average length of feeding period	21.64
Maximum length of feeding period	35
Minimum length of feeding period	12

TABLE X.—*Length of feeding period of larvæ of the first brood of the codling moth, bagged-fruit method, Grand Junction, Colo., 1915.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																				
		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
May 31	1																		1			
June 2	1											1										
3	8									3			1		3		1					
4	11									2	1	1		3		3			1			
5	6							2	2	1								1				
6	14							9	2	1	1		1									
7	15						1	7	1		2	1	1	1						1		
8	4												3	1								
9	11						1	3		1		1	2	1								2
10	6				2			2		1				1								
11	4				2		1		1													
12	1					1																
13	6					3				1		1	1									
14	8						2			1	2	1			1	1						
15	5						2	3														
16	6		1				2		1	1					1							
17	8					1		5		1		1										
18	11					1	2		1		3	1	1		1				1			
19	5				1				1		2	1										
20	3							1			1			1								
21	12							4	2	1	1	1			1	2						
22	1										1											
23	10	1			1			4	1	2	1											
24	8						1	1	1		2	1				1		1				
25	7							4								2					1	
26	7						2			2	1					2						
27	6						1		1	1		2			1							
28	11	1		1		3	1		2	1	2											
29	6				1	2	1		1			1										
30	8		2		2	1	1				1		1									
July 1	7					1	3	2				1										
2	18				7		3	3	1			2		2								
3	7				1		2	3	1													
	242	2	3	1	17	13	26	53	19	20	21	17	11	10	8	11	1	2	3	1	1	2

	Days.
Average length of feeding period	22.7
Maximum length of feeding period	35
Minimum length of feeding period	15

Length of the cocooning period.—The cocooning period is herein considered as extending from the time the larva leaves the fruit until it has pupated. The data given in Table XI, therefore, apply only to the transforming larvæ of the first brood. By reference to this table it will be seen that the cocooning period was recorded for 430 individuals which left the fruit from June 23 to July 26. Of this number, 86 formed their cocoon in 4 days, 85 in 5 days, and 67 in 6 days. The average number of days for all individuals was 6.70, maximum 28, and minimum 1. This minimum cocooning period of 1 day is the shortest period recorded for any larva throughout this and the following season. The cocoon was of normal size, but was constructed very lightly.

TABLE XI.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Grand Junction, Colo., 1915.*

Larvæ left fruit.	Number of individuals.	Length of cocooning period in specified days, being the time from leaving the fruit to the time of pupation.																							Av.	Max.	Min.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	20	22	23	26	28			
																									Days.	*Days.*	*Days.*
June 23	1				1																				4.00	4	4
25	1						1																		6.00	6	6
26	10				3	3	3					1													5.60	11	4
27	21			2	10	6		1	2																4.71	8	3
28	18			2	3	8	2		3																5.22	8	3
29	14		1	1	3	4		3		2															5.43	9	2
30	10				2	2	2		3				1												6.60	12	4
July 1	31		1	1	7	9	6	4	1							1	1								5.87	17	2
2	27	1		1	7	6	6	2	2			2													5.55	11	1
3	17			1	2	3	4	4		1								1						1	7.82	28	3
4	17		1		2	3	2	2	1		2	1	1			1			1						8.00	19	2
5	17				2	2	2	2	2	1			1		1					1	2	1			10.70	23	4
6	35			4	8	6	5	3		1	1		1	2	1		2						1		7.31	26	3
7	18				6	2	3	3	2					2											6.39	13	4
8	28			3	3	6	6			3	2	2	1	1		1									7.00	15	3
9	20			1	2	4	2	3	2	1	3		1		1										7.25	14	3
10	14				3	2		1	3	1		2				1					1				8.64	22	4
11	15		1		2		3	3	3			2				1									7.33	15	2
12	17			1	2	3	1	4		2	2			2											7.29	13	3
13	8				2			2	1	2	1														7.25	10	4
14	10				2	2	2	1	2	1															6.20	9	4
15	13				1	3	1	3	2		2	1													7.15	11	4
16	10				4	2	2				1		1												6.00	12	4
17	10			1	1		3	1	2			1		1											7.20	13	3
18	10		1	2	2	1		2			2														5.50	10	2
19	9			1	1	3	4																		5.11	6	3
20	11			2	1	3	1		2		1		1												6.27	12	3
21	5				2	1	1					1													5.00	11	4
22	6				1		2		2					1											7.50	13	4
23	2						1		1																7.00	8	6
24	2					1			1																6.50	8	5
25	1				1																				4.00	4	4
26	2						2																		6.00	6	6
Total.	430	1	5	23	86	85	67	44	37	15	17	13	8	9	3	5	3	1	1	1	3	1	1	1	6.70	28	1

PUPÆ OF THE FIRST BROOD.

Time of pupation.—The earliest pupation of the transforming larvæ of the first brood occurred June 27, and the latest took place August 4. The larvæ were therefore pupating during a period of slightly more than one month. See Table XII and diagram, figure 5.

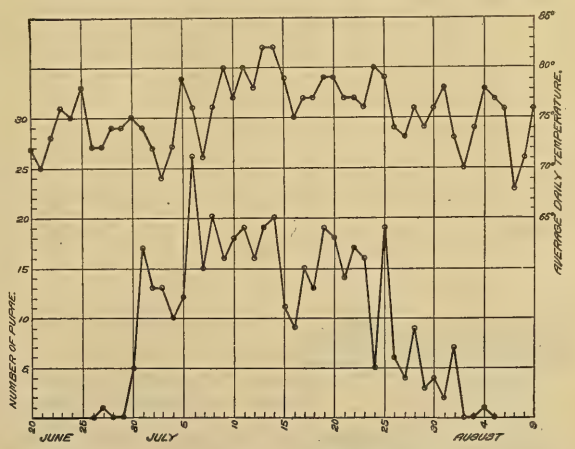


FIG. 5.—Time of pupation of first brood of the codling moth, Grand Junction, Colo., 1915.

Length of pupal stage.—The average length of the pupal stage of pupæ of the first brood is considerably shorter (about 16 days) than that of the spring-brood pupæ, owing to the higher temperatures prevailing during midsummer. As given in Table XIII the average length of the first-brood pupal stage was 11.44 days, maximum 31 days, and minimum 6 days.

TABLE XII.—*Time of pupation of transforming larvæ of the first brood of the codling moth, Grand Junction, Colo., 1915.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
June 27	1	July 7	15	July 15	11	July 23	16	July 31	2
30	5	8	20	16	9	24	5	Aug. 1	7
July 1	17	9	16	17	15	25	19	2	0
2	13	10	18	18	13	26	6	3	0
3	13	11	19	19	19	27	4	4	1
4	10	12	16	20	18	28	9		
5	12	13	19	21	14	29	3	Total	432
6	26	14	20	22	17	30	4		

TABLE XIII.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Grand Junction, Colo., 1915.*

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.																		
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	24	25	31
June 27	1							1												
30	4						4													
July 1	15			1		8	3	3												
2	11				1	3	5		2											
3	12			1	1	5	2	3												
4	6				2	2	1	1												
5	11			1		1	6	2	1											
6	19		1		3	6	5	4												
7	13	1			1	1	8	1	1											
8	16			2		6	5	3												
9	8			1	1	2	2	1												1
10	15				3	4	5	2										1		
11	16				2	3	4	4	1	1									1	
12	12		1		1	2	2	4	2											
13	11					1	6	5		2										
14	17					2	10	2	1	1		1								
15	7						1	5							1					
16	7				1		3	1	2											
17	13			1		2	3	3	3						1					
18	10					2	2	3	1					1			1			
19	17					3	4	4	1	2			1			2				
20	15						4	7	2		2									
21	12					3	3	2		4										
22	12			1	1	1	2	3	3		1									
23	7						2	2	2	1										
24	4						3	1												
25	14				1	1	7	1	3	1										
26	4					3		1												
27	3						1	1	1											
28	6					1	2	1			1	1								
29	2							2												
30	2			1			1													
31	2			1	1															
Aug. 1	4			2				1		1										
	331	1	2	12	19	62	106	74	26	13	4	2	1	1	2	2	1	1	1	1

	Days.
Average length of the pupal stage	11.44
Maximum length of the pupal stage	31
Minimum length of the pupal stage	6

MOTHS OF THE FIRST BROOD.

Time of emergence.—The records of the time of emergence of moths of the first brood were taken from two sources of material: (1) From moths that issued from first-brood larvæ reared in the insectary and (2) from moths that issued from the larvæ collected every

three days from banded apple trees in the Hamilton orchard. The first of these sources was used primarily as a means of establishing the approximate emergence limits of the first-brood moths, while the moths that issued up to August 19 from the larvæ collected in the Hamilton orchard were used for the oviposition study of the first brood. The latter moths were employed for this purpose because their relative rate of emergence approaches normal field conditions more closely than that of the moths from the insectary reared larvæ.

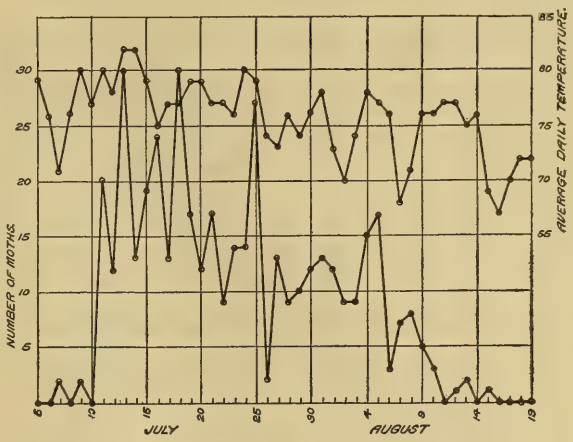


FIG. 6.—Time of emergence of moths of the first brood of the codling moth, Grand Junction, Colo., 1915.

According to the insectary-bred material, the first moth appeared July 7 and the emergence continued daily, except on a few days, to August 15. (See Table XIV and fig. 6.)

TABLE XIV.—*Time of emergence of codling moths of the first brood, from material reared at the insectary, Grand Junction, Colo., 1915.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 7	2	July 19	17	July 29	10	Aug. 7	7
9	2	20	12	30	12	8	8
11	20	21	17	31	13	9	5
12	12	22	9	Aug. 1	12	10	3
13	30	23	14	2	9	12	1
14	13	24	14	3	9	13	2
15	19	25	27	4	15	15	1
16	24	26	2	5	17		
17	13	27	13	6	3	Total..	426
18	30	28	9				

As given in Table XXV, the first moth of the second brood issued August 23, thus leaving a period from August 16 to 22, inclusive, during which no moths issued from larvæ reared at the insectary.

This condition did not obtain with the material from the Hamilton orchard on account of the much larger number of individuals involved, but instead moths issued continuously during the foregoing period as would naturally occur in the field. During the interval August 16 to 22 there was probably an overlapping of the broods

and, for this reason, it was impossible to determine from field material when the last moth of the first brood emerged and when the first moth of the second brood appeared. It is reasonable to infer, however, that the approximate division of the broods occurred during the period of overlapping, and for this reason August 19 was selected as the end of the emergence of the first brood of moths. The time of emergence of the moths of the first brood from the larvæ collected in the Hamilton orchard is given in Table XV and presented graphically in figure 7. According to these data the first moths issued July 10, and emerged in maximum numbers on August 9.

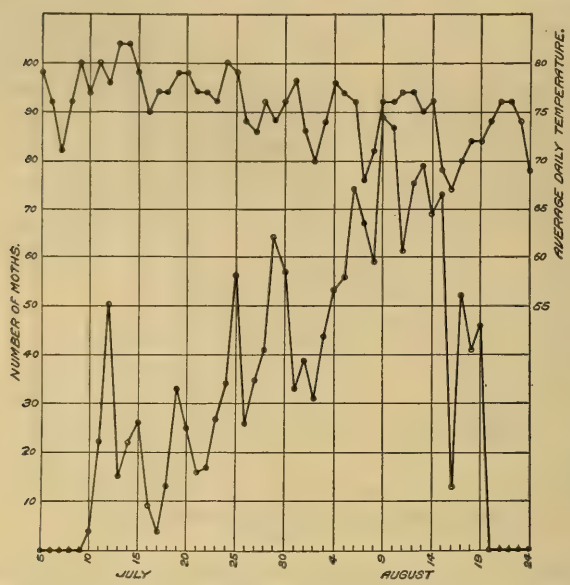


FIG. 7.—Time of emergence of moths of the first brood of the codling moth, Hamilton orchard, Grand Junction, Colo., 1915.

TABLE XV.—*Time of emergence of codling moths of the first brood, reared from field material, Grand Junction, Colo., 1915.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 10	4	July 21	16	Aug. 1	39	Aug. 12	75
11	22	22	17	2	31	13	79
12	50	23	27	3	44	14	69
13	15	24	34	4	53	15	73
14	22	25	56	5	56	16	13
15	26	26	26	6	74	17	52
16	9	27	35	7	67	18	41
17	4	28	41	8	59	19	46
18	13	29	64	9	89		
19	33	30	57	10	87	Total..	1,737
20	25	31	33	11	61		

Number of eggs per female moth.—It will be observed in Table XVI that the total number of eggs deposited by the 945 female moths of the first brood was 44,158 or 46.73 eggs per female moth. This average is nearly four times greater than that made by the spring-brood moths (12.59 eggs) owing, doubtless, to the more favorable climatic factors during the oviposition period of the first-brood moths.

TABLE XVI.—*Oviposition by codling moths of the first brood in rearing cages, Grand Junction, Colo., 1915.*

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male.	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	From first to last oviposition.	From date of emergence to last oviposition.
1	24	10	14	July 12	July 13	July 24	797	1	12	12
2	26	17	9	...do....	July 14	July 25	679	2	12	13
3	15	11	4	July 13	...do....	...do....	501	1	12	12
4	22	11	11	July 14	July 16	July 24	390	2	9	10
5	26	14	12	July 15	...do....	July 28	351	1	13	13
6	9	7	2	July 16	.....	.....	(1)	.....	.....	.....
7	4	2	2	July 17	July 20	July 31	74	3	12	14
8	13	3	10	July 18	...do....	Aug. 1	667	2	13	14
9	33	11	22	July 19	...do....	Aug. 5	1,475	1	17	17
10	25	12	13	July 20	July 22	Aug. 14	624	2	24	25
11	16	8	8	July 21	July 23	Aug. 5	767	2	14	15
12	17	9	8	July 22	July 24	Aug. 6	684	2	14	15
13	27	14	13	July 23	July 25	Aug. 18	427	2	25	26
14	34	12	22	July 24	...do....	Aug. 10	1,089	1	17	17
15	26	11	15	July 25	July 27	Aug. 13	860	2	18	19
16	30	15	15	...do....	...do....	Aug. 12	662	2	17	18
17	26	13	13	July 26	July 28	Aug. 8	602	2	12	13
18	35	12	23	July 27	July 29	Aug. 18	1,127	2	21	22
19	19	4	15	July 28	July 30	...do....	776	2	20	21
20	22	9	13	...do....	...do....	...do....	640	2	20	21
21	33	15	18	July 29	July 31	Aug. 14	517	2	15	16
22	31	10	21	...do....	...do....	Aug. 21	723	2	22	23
23	29	16	13	July 30	Aug. 1	Aug. 25	700	2	25	26
24	28	6	22	...do....	July 31	Aug. 19	737	1	20	20
25	12	6	6	July 31	Aug. 2	Aug. 16	229	2	15	16
26	21	8	13	...do....	Aug. 1	Aug. 20	641	1	20	20
27	18	7	11	Aug. 1	Aug. 5	Aug. 18	114	4	14	17
28	21	11	10	...do....	Aug. 4	...do....	382	3	15	17
29	31	13	18	Aug. 2	...do....	Aug. 26	694	2	23	24
30	22	8	14	Aug. 3	Aug. 5	Aug. 17	512	2	13	14
31	22	7	15	...do....	Aug. 6	Aug. 25	465	3	20	22
32	23	10	13	Aug. 4	...do....	Aug. 28	1,068	2	23	24
33	30	13	17	...do....	...do....	Aug. 22	903	2	17	18
34	30	14	16	Aug. 5	...do....	Aug. 27	703	1	22	22
35	26	16	10	...do....	...do....	Aug. 23	668	1	18	18
36	25	8	17	Aug. 6	Aug. 11	Aug. 22	171	5	12	16
37	22	8	14	...do....	Aug. 8	Aug. 24	1,185	2	17	18
38	27	17	10	...do....	Aug. 10	Aug. 25	200	4	16	19
39	35	18	17	Aug. 7	Aug. 9	Aug. 26	742	2	18	19
40	32	13	19	...do....	...do....	Aug. 28	1,434	2	20	21
41	34	15	19	Aug. 8	Aug. 10	Aug. 25	1,393	2	16	17
42	25	15	10	...do....	...do....	Aug. 29	684	2	20	21
43	26	13	13	Aug. 9	Aug. 11	Aug. 26	568	2	16	17
44	36	16	20	...do....	...do....	Aug. 22	990	2	12	13
45	27	12	15	...do....	Aug. 10	Aug. 28	838	1	19	19
46	34	14	20	Aug. 10	Aug. 12	Aug. 30	755	2	19	20
47	27	10	17	...do....	...do....	Aug. 26	350	2	15	16
48	26	17	9	...do....	...do....	Aug. 24	1,000	2	13	14
49	31	14	17	Aug. 11	Aug. 13	Sept. 2	622	2	21	22
50	30	16	14	...do....	...do....	Aug. 27	980	2	15	16
51	24	14	10	Aug. 12	Aug. 14	Aug. 28	436	2	15	16
52	29	9	20	...do....	...do....	...do....	701	2	15	16
53	22	6	16	...do....	Aug. 13	Aug. 31	456	1	19	19
54	27	10	17	Aug. 13	Aug. 15	Aug. 29	357	2	15	16
55	26	11	15	...do....	Aug. 16	Aug. 28	756	3	13	15
56	26	13	13	...do....	Aug. 15	...do....	591	2	14	15
57	24	14	10	Aug. 14	Aug. 19	Sept. 1	372	5	14	18
58	23	6	17	...do....	Aug. 16	Aug. 31	583	2	16	17
59	22	8	14	...do....	Aug. 15	Aug. 29	700	1	15	15
60	25	10	15	Aug. 15	Aug. 17	Sept. 9	1,103	2	24	25
61	22	11	11	...do....	Aug. 18	Sept. 1	749	3	15	17
62	26	11	15	...do....	Aug. 17	Sept. 2	403	2	17	18
63	13	5	8	Aug. 16	Aug. 21	Aug. 27	29	5	7	11
64	25	12	13	Aug. 17	Aug. 18	Sept. 1	299	1	15	15
65	27	16	11	...do....	Aug. 19	Aug. 28	473	2	10	11
66	21	9	12	Aug. 18	Aug. 20	Sept. 7	502	2	19	20
67	20	9	11	...do....	...do....	Sept. 12	639	2	24	25
68	22	12	10	Aug. 19	Aug. 22	Sept. 7	340	3	17	19
69	24	9	15	...do....	Aug. 20	Sept. 12	565	1	24	24
Average								2.07	16.78	17.85
Maximum								5	25	26
Minimum								1	7	10

[1] No eggs.

Number of male moths..... 766
Number of female moths..... 945
Total number of moths..... 1,711

Total number of eggs..... 44,158
Average number of eggs per female moth... 46.73

Time of oviposition.—One of the most important problems in connection with the control of the codling moth in the Grand Valley was to determine when the earliest eggs of the second brood were deposited and when oviposition was at its height. It is believed that these data could best be secured by using moths that emerged from larvæ collected regularly from banded orchard trees, since the subsequent emergence of the moths would correspond to that which would naturally have occurred in the field. With this in view, the moths from the Hamilton orchard material were kept for oviposition studies, beginning with those that emerged July 12 and ending with those that issued August 19.

As is given in Table XVI, 69 cages containing a total of 1,711 moths were employed and, as will be noted therein, the average number of days before oviposition was 2.07, maximum 5, and minimum 1; the average number of days from the first to the last oviposition was 16.78, maximum 25, and minimum 7; the average number of days from the date of emergence to last oviposition was 17.85, maximum 26, and minimum 10.

According to this table the first eggs were deposited July 13 by moths that emerged July 12 and the last eggs were laid September 12. A few moths issued July 10 and 11 from the Hamilton orchard material, and, in addition to these, several moths emerged from insectary-bred and other material as early as July 7. These moths were confined together in a cage and deposited the earliest second-brood eggs on July 11, as shown in figure 8, page 31.

Length of life of moths.—Table XVII includes the summary of records of the length of life of 1,719 male and female moths of the first brood. The data in this table show that the average length of life of 769 male moths was 11.86 days, of 950 female moths 12.68 days; the maximum length of life of male moths 41 days, of female moths 35 days; the minimum length of life of male moths 1 day, of female moths 1 day. As has been frequently observed in other studies of the life history of the codling moth with but few exceptions, the average life of the female moth is longer than that of the male.

TABLE XVII.—*Length of life of male and female codling moths of the first brood in captivity; summary of records of 1,719 individual moths, Grand Junction, Colo., 1915.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	4	1	1	16	26	16	64	31	1	31	0
2	8	2	2	17	29	17	39	32	0	32	0
3	24	3	10	18	27	18	36	33	0	33	0
4	15	4	10	19	10	19	21	34	0	34	0
5	44	5	16	20	12	20	20	35	0	35	1
6	48	6	35	21	16	21	13	36	1	36	0
7	55	7	35	22	7	22	16	37	1	37	0
8	55	8	61	23	6	23	7	38	1	38	0
9	38	9	72	24	7	24	7	39	0	39	0
10	68	10	75	25	8	25	3	40	0	40	0
11	49	11	103	26	7	26	5	41	1	41	0
12	58	12	96	27	4	27	3				
13	45	13	74	28	3	28	3	Total.	769	Total.	950
14	39	14	65	29	2	29	3				
15	46	15	54	30	4	30	0				

Average length of life of male moths, 11.86 days; female moths, 12.68 days.
Maximum length of life of male moths, 41 days; female moths, 35 days.
Minimum length of life of male moths, 1 day; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Life cycle, stock-jar feeding method.—The length of the life cycle of the first generation of the codling moth, by the stock-jar feeding method, is given in Table XVIII and, as shown therein, includes the time from the deposition of the egg to the emergence of the moth. The complete life cycle extends from the deposition of the eggs of one generation to the deposition of the eggs of the next, and it will therefore be necessary to add 2.07 days, the average number of days from emergence of moth to first oviposition, to the figures in Table XVIII to determine the complete life cycle. It will be noted in this table that the data include 221 individuals, giving the incubation period, and the average, maximum, and minimum length of the larval feeding period, the cocooning period, the pupal period, and the life cycle. The summarized averages are: Incubation period 9.91 days, larval feeding period 20.75 days, cocooning period 6.99 days, pupal period 11.64 days, and life cycle 49.30 days, complete life cycle 51.37 days.

Life cycle, bagged-fruit feeding method.—In Table XIX the life cycle of the first generation of the codling moth, by the bagged-fruit method, is given for 109 individuals. The summarized average figures are: Incubation period 10.55 days, larval feeding period 22.18 days, cocooning period 5.40 days, pupal period 11.03 days, life cycle 49.18 days, complete life cycle 51.25 days.

TABLE XVIII.—*Life cycle of the first generation of the codling moth, as observed by rearing, stock-jar feeding method, Grand Junction, Colo., 1915.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 13	1	14	27.00	27	27	4.00	4	4	12.00	12	12	57.00	57	57
23	4	13	22.25	23	21	3.50	5	3	10.25	11	8	49.00	50	47
24	11	13	21.45	25	19	5.36	11	2	10.81	13	6	50.63	54	48
24	1	14	20.00	20	20	4.00	4	4	11.00	11	11	49.00	49	49
26	2	13	20.00	21	19	5.00	8	2	9.00	10	8	47.00	48	46
27	9	13	19.77	23	18	5.22	9	3	10.33	12	8	48.33	53	45
29	11	12	20.63	22	18	5.09	7	3	11.27	13	10	49.00	51	45
29	15	13	21.80	27	19	6.66	9	3	13.26	31	9	54.73	72	47
31	3	12	20.66	22	19	14.33	28	4	10.66	12	9	57.66	70	46
June 1	2	12	20.50	21	20	7.00	7	7	10.00	11	9	49.50	51	48
2	12	12	21.08	25	18	9.25	23	3	11.33	13	7	53.66	66	46
4	31	11	19.83	27	14	6.77	20	3	11.45	20	7	49.06	65	39
6	15	10	22.20	32	18	8.40	14	4	13.13	21	9	53.73	63	45
9	20	8	20.55	26	15	7.55	14	2	11.60	14	8	47.70	56	38
10	23	8	20.86	29	17	7.17	13	4	11.47	15	9	47.52	56	40
11	13	8	20.84	26	19	6.84	13	3	12.38	25	10	48.07	57	42
12	10	8	21.20	24	18	7.60	11	4	12.10	16	10	48.90	53	45
13	6	8	21.00	24	19	6.66	9	4	12.50	14	11	48.16	52	45
15	3	7	24.66	29	20	10.33	11	9	9.66	11	8	51.66	55	46
16	3	7	22.66	25	20	6.66	10	2	12.00	14	10	48.33	50	46
16	1	8	18.00	18	18	5.00	5	5	13.00	13	13	44.00	44	44
18	1	7	21.00	21	21	12.00	12	12	11.00	11	11	51.00	51	51
19	3	7	20.00	24	17	7.66	9	6	12.00	15	10	46.66	54	42
20	2	7	18.50	20	17	5.00	6	4	11.00	12	10	41.50	45	38
21	6	7	21.50	26	16	7.16	9	4	11.16	12	10	46.83	53	44
21	4	8	17.50	19	15	6.50	8	5	11.00	12	10	43.00	46	38
23	2	7	19.50	20	19	8.50	12	5	9.50	11	8	44.50	47	42
25	1	7	16.00	16	16	5.00	5	5	11.00	11	11	39.00	39	39
26	3	7	18.33	23	16	6.00	6	6	12.66	14	11	44.00	50	40
27	2	7	17.50	18	17	6.00	6	6	12.00	12	12	42.50	43	42
30	1	6	17.00	17	17	6.00	6	6	12.00	12	12	41.00	41	41
	221	9.91	20.75	32	14	6.99	28	2	11.64	31	6	49.30	72	38

[1] Add 2.07 days for complete life cycle.

TABLE XIX.—*Life cycle of the first generation of the codling moth, as observed by rearing, bagged-fruit feeding method, Grand Junction, Colo., 1915.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 16	1	15	32.00	32	32	5.00	5	5	10.00	10	10	62.00	62	62
22	1	11	25.00	25	25	4.00	4	4	10.00	10	10	50.00	50	50
23	5	11	26.40	30	23	4.80	6	4	11.00	12	10	53.20	59	49
23	8	12	27.37	32	23	6.25	15	3	10.62	13	9	56.25	63	50
23	5	13	21.80	23	21	4.60	6	4	10.40	11	10	49.80	51	49
24	8	13	21.12	22	21	4.12	5	3	10.75	13	9	49.00	52	48
24	9	14	22.22	25	21	5.66	8	4	10.55	12	9	52.44	57	49
26	3	13	26.33	27	26	7.33	12	4	9.00	11	8	55.66	60	51
27	6	13	23.66	27	20	9.33	22	1	12.33	17	10	58.33	74	49
29	4	12	19.50	21	18	7.00	8	6	10.25	11	9	48.75	50	47
29	2	13	19.00	20	18	5.00	5	5	11.50	12	11	48.50	50	47
31	1	12	19.00	19	19	4.00	4	4	11.00	11	11	46.00	46	46
June 1	5	12	21.20	26	19	4.80	6	4	10.80	12	9	48.80	55	44
2	2	12	21.50	23	20	3.00	4	2	11.50	12	11	48.00	51	45
4	3	11	20.33	21	20	4.66	5	4	11.00	12	10	47.00	48	46
6	5	10	21.40	28	16	5.40	8	4	9.60	11	8	46.40	54	42
9	4	8	20.50	21	19	4.25	5	3	11.50	13	10	44.25	46	41
10	3	8	22.33	28	19	9.66	15	6	13.33	15	11	53.33	57	46
13	8	8	23.25	29	21	4.75	7	4	12.75	19	11	48.75	53	44
16	4	8	21.75	24	20	4.25	5	4	11.75	12	11	45.75	48	43
18	1	7	21.00	21	21	5.00	5	5	12.00	12	12	45.00	45	45
19	4	7	22.50	24	20	4.50	6	3	10.75	12	10	44.75	47	43
21	3	7	17.00	19	15	4.33	5	4	10.66	11	10	39.00	41	36
21	3	8	21.33	25	19	4.66	5	4	11.66	12	11	45.66	50	43
23	3	7	18.00	20	16	4.00	5	3	10.00	11	9	39.00	41	38
24	4	7	20.50	21	20	4.75	6	4	12.25	16	10	44.50	50	42
25	4	7	18.75	21	18	6.50	10	3	10.00	13	8	42.25	44	41
	109	10.55	22.18	32	15	5.40	22	1	11.03	19	8	49.18	74	36

[1] Add 2.07 days for complete life cycle.

THE SECOND GENERATION.

Eggs of the Second Brood.

Time of deposition.—Table XX shows the number of eggs deposited daily by moths of the first brood in oviposition jars in the insectary. It will be noted that the period of egg deposition extended from July 11 to September 15, inclusive, and that during this interval

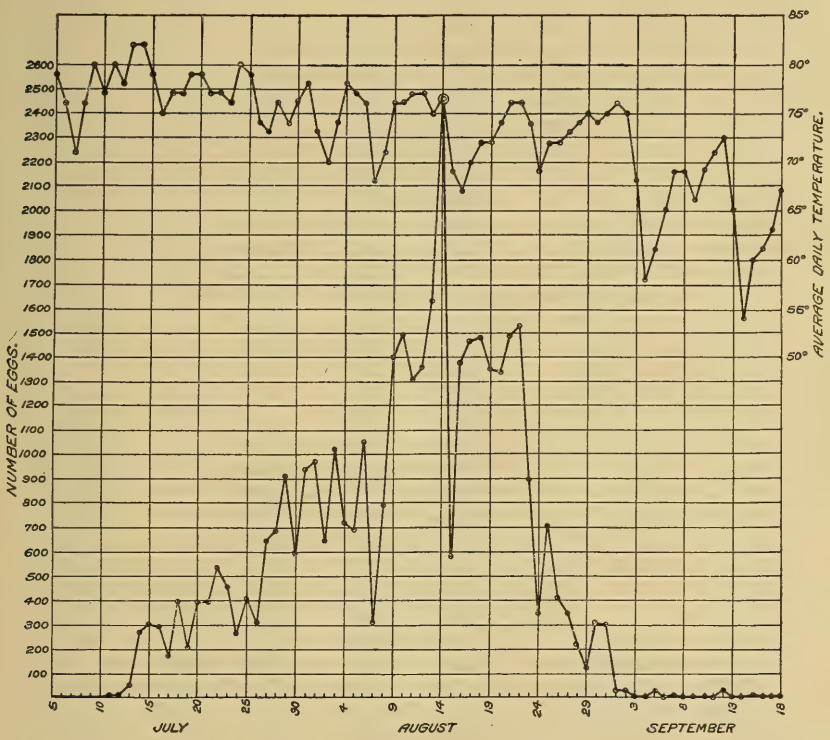


Fig. 8.—Time of deposition of eggs of the second brood of codling moth, Grand Junction, Colo., 1915.

38,485 eggs were deposited. The largest number deposited in any one day was 2,452 on August 14, as will be seen by reference to this table. The time of maximum deposition, as shown in figure 8, occurred about midway between the earliest and latest deposition.

TABLE XX.—*Time of deposition, length of incubation, and time of hatching of eggs of the second brood of the codling moth, Grand Junction, Colo., 1915.*

Observation No.	Number of eggs deposited.	Date—				Number of eggs hatched.	Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.		Red ring.	Black spot.	
							Days.	*Days.*	*Days.*
1	6	July 11	July 13			0	2		
2	10	July 12	...do....	July 17	July 19	8	1	5	7
3	53	July 13	July 14	July 16	...do...	50	1	3	6
4					July 20	2			7
5	271	July 14	July 15	July 19	...do....	179	1	5	6
6					July 21	43			7
7	303	July 15	July 16	July 20	...do....	170	1	5	6
8	288	July 16	July 17	July 21	July 22	282	1	5	6
9	176	July 17	July 18	...do....	July 23	169	1	4	6
10	398	July 18	July 19	July 23	July 24	378	1	5	6
11					July 25	16			7
12	208	July 19	July 20	July 23	July 24	94	1	4	5
13					July 25	106			6
14	396	July 20	July 21	July 24	July 26	376	1	4	6
15					July 27	12			7
16	395	July 21	July 22	July 25	July 26	51	1	4	5
17					July 27	300			6
18	539	July 22	July 24	July 26	...do....	32	2	4	5
19					July 28	496			6
20	455	July 23	July 25	July 28	July 29	446	2	5	6
21					July 30	5			7
22	261	July 24	July 25	July 28	...do....	245	1	4	6
23					July 31	13			7
24	404	July 25	July 28	July 30	...do....	315	3	5	6
25					Aug. 1	57			7
26	309	July 26	July 28	July 31	...do....	250	2	5	6
27					Aug. 2	15			7
28	645	July 27	July 28	Aug. 1	...do....	555	1	5	6
29					Aug. 3	58			7
30	684	July 28	July 31	Aug. 2	...do....	588	3	5	6
31					Aug. 4	62			7
32	909	July 29	July 31	Aug. 3	...do....	709	2	5	6
33					Aug. 5	64			7
34	595	July 30	Aug. 1	Aug. 4	...do....	303	2	5	6
35					Aug. 6	256			7
36	937	July 31	Aug. 2	Aug. 5	...do....	581	2	5	6
37					Aug. 7	311			7
38	966	Aug. 1	Aug. 3	Aug. 6	...do....	58	2	5	6
39					Aug. 8	831			7
40	641	Aug. 2	Aug. 4	Aug. 7	...do....	340	2	5	6
41					Aug. 9	244			7
42					Aug. 10	38			8
43	1,013	Aug. 3	Aug. 5	Aug. 8	Aug. 9	223	2	5	6
44					Aug. 10	760			7
45	720	Aug. 4	Aug. 6	Aug. 9	...do....	554	2	5	6
46					Aug. 11	137			7
47	693	Aug. 5	Aug. 6	Aug. 10	...do....	464	1	5	6
48					Aug. 12	194			7
49	1,045	Aug. 6	Aug. 8	Aug. 11	...do....	543	2	5	6
50					Aug. 13	408			7
51	314	Aug. 7	Aug. 10	Aug. 12	...do....	223	3	5	6
52					Aug. 14	69			7
53	787	Aug. 8	Aug. 10	Aug. 13	...do....	401	2	5	6
54					Aug. 15	299			7
55	1,400	Aug. 9	Aug. 10	Aug. 14	...do....	1,064	1	5	6
56					Aug. 16	224			7
57	1,495	Aug. 10	Aug. 11	Aug. 15	...do....	837	1	5	6
58					Aug. 17	493			7
59					Aug. 18	75			8
60	1,311	Aug. 11	Aug. 12	Aug. 16	Aug. 17	105	1	5	6
61					Aug. 18	1,091			7
62					Aug. 19	66			8
63	1,358	Aug. 12	Aug. 13	Aug. 17	Aug. 18	81	1	5	6
64					Aug. 19	1,127			7
65					Aug. 20	95			8
66	1,626	Aug. 13	Aug. 14	Aug. 19	...do....	1,480	1	6	7
67	2,452	Aug. 14	Aug. 16	Aug. 20	Aug. 21	2,280	2	6	7
68	583	Aug. 15	Aug. 17	Aug. 21	Aug. 22	501	2	6	7
69					Aug. 23	52			8
70	1,378	Aug. 16	Aug. 18	Aug. 21	Aug. 22	978	2	5	6
71					Aug. 23	289			7
72	1,462	Aug. 17	Aug. 20	Aug. 22	...do....	1,067	3	5	6
73					Aug. 24	380			7
74	1,485	Aug. 18	Aug. 20	Aug. 23	...do....	1,292	2	5	6
75					Aug. 25	163			7

TABLE XX.—*Time of deposition, length of incubation, and time of hatching of eggs of the second brood of the codling moth, Grand Junction, Colo., 1915*—Continued.

Observation No.	Number of eggs deposited.	Date—				Number of eggs hatched.	Appearance of—		Incubation period.
		Deposited	Red ring.	Black spot.	Hatched.		Red ring.	Black spot.	
							Days.	*Days.*	*Days.*
76	1,353	Aug. 19	Aug. 21	Aug. 24	Aug. 25	352	2	5	6
77					Aug. 26	947			7
78	1,340	Aug. 20	Aug. 22	Aug. 25	...do...	456	2	5	6
79					Aug. 27	616			7
80	1,490	Aug. 21	Aug. 24	Aug. 26	...do...	45	3	5	6
81					Aug. 28	1,341			7
82	1,526	Aug. 22	Aug. 24	Aug. 27	...do...	889	2	5	6
83					Aug. 29	504			7
84	895	Aug. 23	Aug. 26	Aug. 29	Aug. 30	841	3	6	7
85	343	Aug. 24	...do...	Aug. 30	Aug. 31	278	2	6	7
86					Sept. 1	38			8
87	702	Aug. 25	Aug. 27	Aug. 30	Aug. 31	407	2	5	6
88					Sept. 1	288			7
89	412	Aug. 26	Aug. 28	Sept. 1	Sept. 2	325	2	6	7
90					Sept. 3	21			8
91	348	Aug. 27	Aug. 28	Sept. 1	...do...	282	1	5	7
92					Sept. 5	28			9
93	224	Aug. 28	Aug. 29	Sept. 2	Sept. 3	146	1	5	6
94					Sept. 4	11			7
95					Sept. 5	45			8
96	129	Aug. 29	Aug. 31	Sept. 4	...do...	18	2	6	7
97					Sept. 6	59			8
98					Sept. 7	31			9
99	309	Aug. 30	Sept. 1	Sept. 6	...do...	133	2	7	8
100					Sept. 8	154			9
101					Sept. 9	19			10
102	300	Aug. 31	Sept. 1	Sept. 7	Sept. 8	171	1	7	8
103					Sept. 9	93			9
104					Sept. 10	21			10
105	35	Sept. 1	Sept. 3	Sept. 8	...do...	30	2	7	9
106					Sept. 11	4			10
107	29	Sept. 2	Sept. 6	Sept. 10	...do...	22	4	8	9
108					Sept. 12	6			10
109	28	Sept. 5	Sept. 8	Sept. 13	Sept. 14	22	3	8	9
110					Sept. 15	1			10
111					Sept. 16	1			11
112	4	Sept. 6	Sept. 8	Sept. 14	Sept. 15	3	2	8	9
113					Sept. 16	1			10
114	7	Sept. 7	Sept. 9	Sept. 15	...do...	1	2	8	9
115					Sept. 17	1			10
116	2	Sept. 8	Sept. 11	Sept. 17	Sept. 18	2	3	9	10
117	3	Sept. 9	...do...	...do...	Sept. 19	2	2	8	10
118					Sept. 20	1			11
119	2	Sept. 10	Sept. 12	Sept. 18	...do...	2	2	8	10
120	32	Sept. 12	Sept. 14	Sept. 20	Sept. 22	26	2	8	10
121	1	Sept. 15	Sept. 18	Sept. 23	Sept. 24	1	3	8	9
Total.	38,485					35,804			
Av...							1.85	5.54	7.22
Max..							4	8	11
Min..							1	3	6

Length of incubation.—A record of the observations of the embryological development and incubation period of the eggs of the second brood will be found in Table XX. It will be observed that the length of the incubation period was increased toward the latter part of the season, as the temperatures became lower. The average number of days from the time of deposition to the appearance of the red ring was 1.85, maximum 4 days, and minimum 1 day; the average number of days from the time of deposition to the appearance of the

black spot was 5.54 days, maximum 8 days, and minimum 3 days; the average length of the incubation period was 7.22 days, maximum 11 days, and minimum 6 days.

Larvæ of the Second Brood.

Time of hatching.—By reference to Table XX it will be seen that the time of hatching of eggs of the second brood extended over a period of more than two months, namely, from July 19 to September 24. The largest number hatching in any one day was 2,280 on August 21, a date which is just midway between that when the first

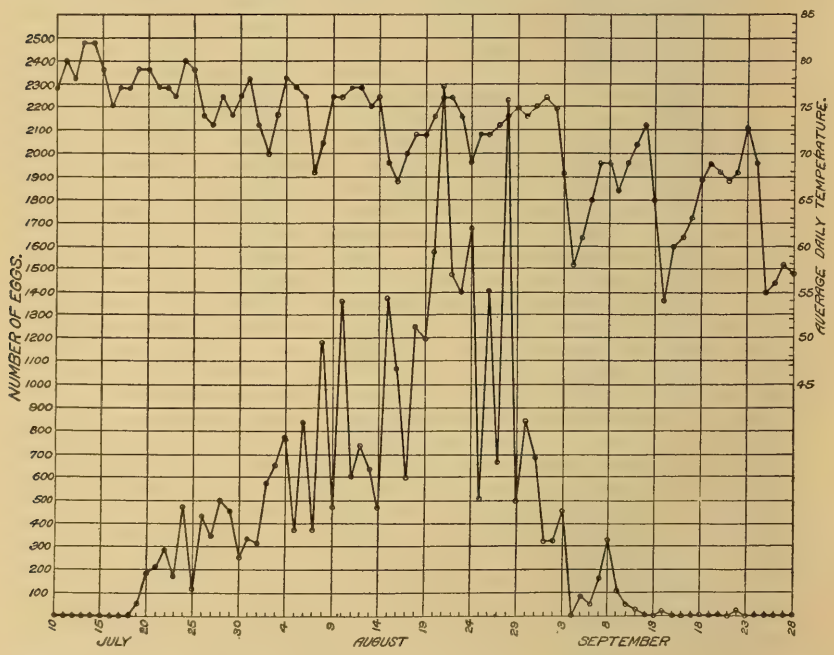


Fig. 9.—Time of hatching of eggs of the second brood of the codling moth, Grand Junction, Colo., 1915.

larvæ of this brood appeared and the date when the last larva hatched. In figure 9 the daily hatching record is shown diagrammatically with average daily temperatures.

Length of the feeding period.—The length of the feeding period of larvæ of the second brood was established by means of the stock-jar method (see p. 8). The observations of 1,939 larvæ are presented in Table XXI, in which it will be noted that the feeding periods during the warmer weather of July and August were considerably shorter than those during September and October. The first larvæ of the second brood entered the fruit July 19, and although some of

the larvæ hatched and commenced feeding as late as September 24, none that entered the fruit later than September 12 successfully completed its feeding period. The average length of the feeding period was 28.69 days, the maximum 67 days, and the minimum 15 days.

TABLE XXI.—*Length of feeding period of larvæ of the second brood of the codling moth, stock-jar method, Grand Junction, Colo., 1915.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																							
		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
July 19	20			3	1	2	2		3	2		2	2	1	1		1								
20	43		1	1	1	2	5	7	4	4	4	3	3	2	3	2				1					
21	81		1	5	2	10	12	5	5	7	5	4	3	2	5	2	3		3		5		1		1
22	74				2	7	6	8	13	8	4	3	7	2	3	5	4			1			1		
23	28					2	1	5	3		1	1	3	1	3	2	1		2		1			2	
24	67			1	1	6		15	10	9	6	2	2		3	5			1	1	1			1	1
25	20				2		2	3	2	5		1	1		2	1			1						
26	48					2	6		5	7	2	11	3	1	2		4		2			1	2		
27	44				1	2	2	2	9	2	5	3	2	2	1	3	2	2	1	1	1	3			
28	38			2		1	4	5	6	3		7	4				1	1			2	1			
29	50				2		5	7	4	6	6	3	2	4	3	1			5		2				
30	39					1	3	4	4	3	5	7	4	2	1	1				1		2		1	
31	58					4	11	10	5	6	5	3	5	1	1	2	3	1	1						
Aug. 1	52	1			2	3	4	7	4	5	5	3	4	2	1	4	1	1	1		1			1	
2	62		1			1	5	10	5	7	7	4	6	1	3	3	3		2	2			1		
3	52					2	4	1	11	2	6	7	6	4	3	2		1			1	2			
4	37					1	1	4	2	4	4	3	3	2	3	3	2	2	1	1				1	
5	56						2	5	3	4	7	4	7	8	2	3	1	2	2		3	1			1
6	64							2	1	12	6	7	7	5	2	2	2	4	3		2	2		2	
7	51		1					3	4	5	13	5	4	3	1		2	1	1		1		1		1
8	81						3	7	13	6	16	9	2	4	5	2	1	2	2		2			1	2
9	55						1	11	7	7	8	3	2	2	2		2	2	2			4			
10	57				3	1	3	2	3	6	8	2	2	5	1	2	4	1	1	3	4	1			
11	28			1			2	2	3	3	1	2		3	2		3								3
12	47					3	4	4	6	2	1	2	1	6	4	4		5	1		3				
13	49				1		2	1	2	3	6	6	3	1	3	3	6	2			3				1
14	38					5	2			7	1	2	7			4	1			1	1	1			4
15	35				1				2		4	4	3	2	1	2			2	1	5	1	2		
16	44					1				1	8	4	6	2	6		1			2	1	2	3	1	2
17	29					1		1	4		2	5	2	2	5			1							1
18	40					1				2	3	7	1		2	3	2	1	3	3	2	2		3	
19	39								1	1	10		1	1	2		4	2	2	1	3	5	1	1	
20	34									1	5	4	1		4	6		1	1	3	2	1			1
21	41												3	10	9	5		4	2	1	3				1
22	2																		2						
23	22									1	1	1		3	1	1	6	2	6						
24	21							1			1			2	2	2	2	2				2		2	1
25	27									1	1	1	1	4	4	1	1	2		2	2				2
26	40												4	2	1	3	3	2	2	6				1	
27	29												3	2	4	1			2			1	2		1
28	21													2	3	3	1		3	1		1	1		
29	32												3	1		3			1	5	3	1		1	2
30	24													1	1	2		1	2	1	1		2	1	
31	21													1		1	2	2		2					
Sept. 1	17																		2						
		1	4	13	19	57	93	132	144	142	167	135	123	99	105	89	69	47	62	40	56	35	15	19	25

TABLE XXI.—*Length of feeding period of larvæ of the second brood of the codling moth, stock-jar method, Grand Junction, Colo., 1915*—Continued.

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																											
		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
July 24	67	2																												
28	38		1																											
Aug. 1	52	1	1																											
2	62	1																												
5	56										1																			
6	64	2		1			1					1																		
7	51	1		1		1	1		1																					
8	81			1	1	1				1																				
9	55											2																		
10	57				1	1								3																
11	28	2	1																											
12	47		1																											
13	49	2	1		1		1	1																						
14	38	1	1																											
15	35		3			1	1																							
16	44		1				2	1																						
17	29	1			1			1	2																					
18	40		1	1		3																								
19	39	1		1	2																									
20	34	2	1	1																										
21	41	1					1			1																				
24	21	2	1	1																										
25	27	1			2													1				1								
26	40		1	1		2	1	1	1	4	1								2		2									
27	29	3		1	1		1	1		3		1						1			1								1	
28	21		1				2											1	2											
29	32	4		1	1													4			1						1			
30	24	1	2		3			1		3												2								
31	21		2	2		1		1			1			1		2			1	2										
Sept. 1	17		1	3						1			3	1	2	2			1						1					
2	12			1				1		1	1		1		1	1							1	2			1			1
3	16		2			2		1	1	1	1				1								3		1	2	1			
4	12	2			1					1						1		1			2	3			1					
5	8							1	1		1							1			1					1		1		1
6	10				1			1		1						1	1				1			3				1		
7	8							1			1	2	1		1			1	1											
8	3														2					1										
9	9						1							1			2	1	1	1		1				1				
10	3														1						2									
12	1																1													
	1,939	29	22	16	15	12	12	12	6	17	7	6	5	6	8	7	4	11	8	4	10	7	4	5	3	4	3	2	1	2

	Days.
Average length of feeding period	28.69
Maximum length of feeding period	67
Minimum length of feeding period	15

Length of the cocooning period.—The time consumed in constructing the cocoon by the transforming larvæ of the second brood will be found in Table XXII. As will be noted therein, the average cocooning period for 20 individuals was 9.35 days, the maximum 31 days, and the minimum 3 days. The maximum here reported is the longest cocooning period secured for any larva throughout this and the following season. As will be seen from Table XXII, this individual left the fruit September 1 and pupated October 2.

TABLE XXII.—*Length of cocooing period of transforming larvæ of the second brood of the codling moth, Grand Junction, Colo., 1915.*

Larvæ left fruit.	Number of individuals.	Length of cocooning period in specified days, being the time from leaving the fruit to the time of pupation.											Average.	Maximum.	Minimum.
		3	4	5	6	7	8	10	11	12	16	31			
													Days.	*Days.*	*Days.*
Aug. 5	2	....	....	....	....	....	....	1	....	1	....	....	11.00	12	10
7	1	....	....	....	....	....	....	....	....	1	....	....	12.00	12	12
8	1	....	1	....	....	....	....	....	....	....	....	....	4.00	4	4
9	1	....	....	1	....	....	....	....	....	....	....	....	5.00	5	5
10	1	....	....	....	1	....	....	....	....	....	....	....	6.00	6	6
11	1	....	....	....	....	....	....	1	....	....	....	....	10.00	10	10
12	1	1	....	....	....	....	....	....	....	....	....	....	3.00	3	3
13	1	....	....	....	....	....	....	....	....	....	1	....	16.00	16	16
16	2	....	....	....	1	1	....	....	....	....	....	....	6.50	7	6
19	1	....	....	....	1	....	....	....	....	....	....	....	6.00	6	6
20	3	....	....	....	....	1	1	1	....	....	....	....	8.33	10	7
22	1	....	....	1	....	....	....	....	....	....	....	....	5.00	5	5
28	1	....	....	....	....	....	....	....	....	1	....	....	12.00	12	12
Sept. 1	1	....	....	....	....	....	....	....	....	....	....	1	31.00	31	31
3	1	....	....	....	....	....	....	....	1	....	....	....	11.00	11	11
7	1	....	....	....	1	....	....	....	....	....	....	....	6.00	6	6
Total.	20	1	1	2	4	2	1	3	1	3	1	1	9.35	31	3

PUPÆ OF THE SECOND BROOD.

Time of pupation.—It will be observed in Table XXIII and figure 10 that pupation of the second brood occurred from August 12 to October 2, inclusive.

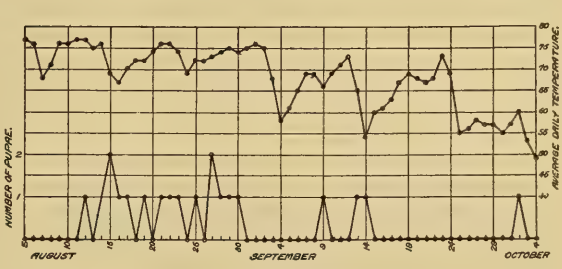


FIG. 10.—Time of pupation of the second brood of the codling moth, Grand Junction, Colo., 1915.

Length of the pupal stage.—In Table XXIV the length of the pupal stage of 16 pupæ of the second brood is given and, as recorded therein, the average was 15.62 days, the maximum 31 days, and the minimum 11 days.

TABLE XXIII.—*Time of pupation of transforming larvæ of the second brood of the codling moth, Grand Junction, Colo., 1915.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
Aug. 12	1	Aug. 19	1	Aug. 27	2	Sept. 13	1
14	1	21	1	28	1	14	1
15	2	22	1	29	1	Oct. 2	1
16	1	23	1	30	1		
17	1	25	1	Sept. 9	1	Total..	20

TABLE XXIV.—*Length of the pupal stage of pupæ of the second brood of the codling moth, Grand Junction, Colo., 1915.*

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.							
		11	12	13	14	16	19	21	31
Aug. 12	1	1							
14	1	1							
15	1				1				
17	1		1						
19	1			1					
22	1					1			
23	1				1				
25	1			1					
27	2				2				
28	1							1	
29	1				1				
30	1						1		
Sept. 9	1				1				
13	1								1
14	1						1		
	16	2	1	2	6	1	2	1	1

	Days.
Average length of pupal stage	15.62
Maximum length of pupal stage	31
Minimum length of pupal stage	11

MOTHS OF THE SECOND BROOD.

Time of emergence.—The time of emergence of moths of the second brood reared from insectary-bred material is presented in Table

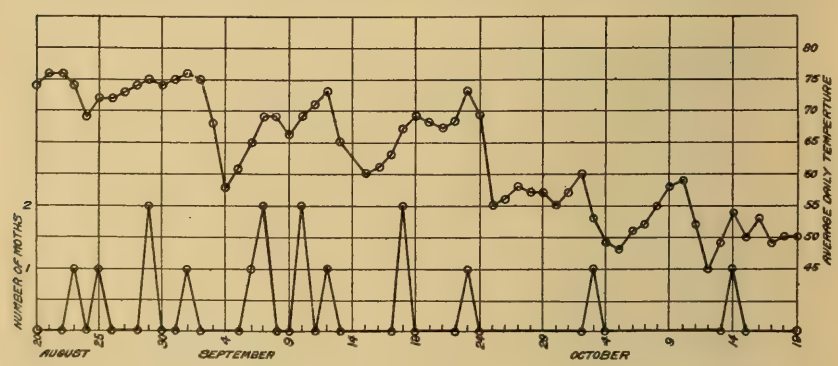


FIG. 11.—Time of emergence of moths of the second brood of the codling moth, Grand Junction, Colo., 1915.

XXV and figure 11. The first moth of this brood issued August 23, the last October 14; thus the emergence extended over a period of more than one and a half months.

TABLE XXV.—*Time of emergence of codling moths of the second brood, Grand Junction, Colo., 1915.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
Aug. 23	1	Sept. 12	1
25	1	18	2
29	2	23	1
Sept. 1	1	Oct. 3	1
6	1	14	1
7	2		
10	2	Total...	16

LIFE CYCLE OF THE SECOND GENERATION.

In Table XXVI are given the summarized data showing the average length of each period in the life cycle of the codling moth as derived from observations of 16 individuals of the second generation reared by the stock-jar feeding method. It will be noted that the average length of the incubation period was 6.12 days, the larval feeding period 20.49 days, the cocooning period 8.56 days, the pupal period 15.62 days, and the average life cycle 50.81 days.

TABLE XXVI.—*Life cycle of the second generation of the codling moth, as observed by rearing by the stock-jar feeding method, Grand Junction, Colo., 1915.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
July 13	2	6	18.50	20	17	8.00	12	4	11.50	12	11	44.00	47	41
14	3	6	19.33	24	16	12.66	16	10	13.66	14	13	51.66	60	46
16	2	6	21.50	25	18	5.50	6	5	13.50	16	11	46.50	53	40
21	1	6	20.00	20	20	7.00	7	7	14.00	14	14	47.00	47	47
25	4	6	19.75	20	19	7.75	10	6	16.75	21	13	50.25	55	44
27	1	6	20.00	20	20	5.00	5	5	14.00	14	14	45.00	45	45
31	1	6	28.00	28	28	11.00	11	11	19.00	19	19	64.00	64	64
Aug. 3	1	7	18.00	18	18	12.00	12	12	14.00	14	14	51.00	51	51
6	1	7	25.00	25	25	6.00	6	6	31.00	31	31	69.00	69	69
	16	6.12	20.49	28	16	8.56	16	4	15.62	31	11	50.81	69	40

THE THIRD GENERATION.

Owing to the small number of moths of the second brood that were reared at the insectary, data of the third generation were not secured. The moths of the second brood deposited third-brood eggs but none of these hatched. Complete data of the third generation, however, were obtained in 1916 (see p. 75–78).

CODLING-MOTH BAND STUDIES OF 1915.

Two orchards were selected for banding purposes. The first of these, known as the Edwards orchard, was unsprayed; it was located about one-half mile west of the insectary. The second, or Hamilton

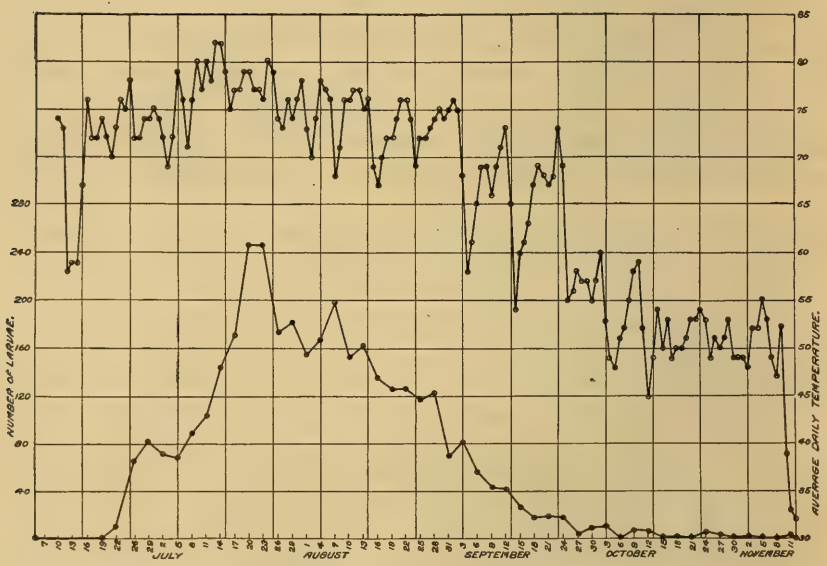


FIG. 12.—Number of larvæ of the codling moth collected from banded trees, Edwards orchard, Grand Junction, Colo., 1915.

orchard, was well sprayed throughout the season, and was located about 2 miles west and 3½ miles north of the insectary. Certain trees in each orchard were scraped to remove the loose bark on the trunk and larger limbs and were then banded with a strip of burlap cloth, folded to three thicknesses, having a width after folding of about 5 inches. These bands were removed every three days with one exception in both orchards when the interval was four days. The larvæ of each collection were kept separate and were allowed to spin up in corrugated pasteboard strips at the insectary for further study.

In Table XXVII and figure 12 will be found the data for the Edwards orchard. As noted therein, the first larval collection was made June 22 and the last November 11, and during this period 3,551 larvæ were secured. The maximum number of larvæ collected at any one time was 250, and this number was successively obtained on July 20 and 23. During the season of 1915, 1,417 moths, or 39.96

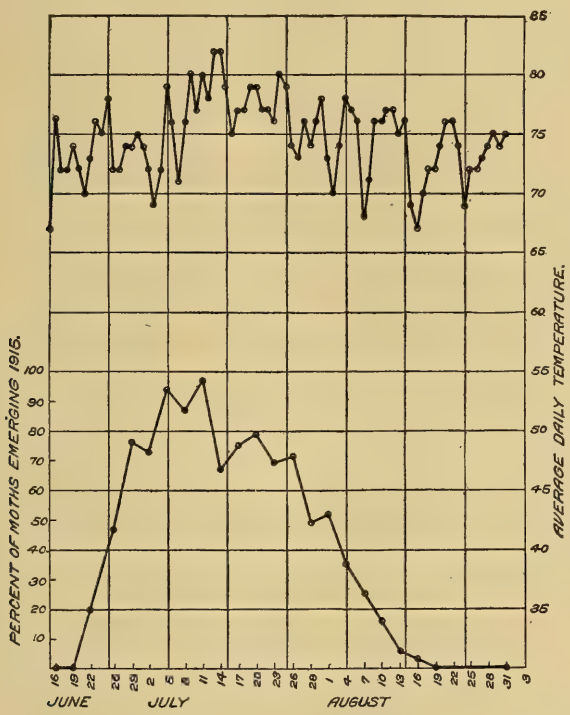


FIG. 13.—Percentage of codling moths emerging from band-collected material, Edwards orchard, Grand Junction, Colo., 1915.

per cent. of the total number of larvæ collected, issued from the band material. The percentage of moths emerging from each collection is shown in figure 13. No moths from this orchard emerged in 1915 from larvæ collected after August 16 In the following spring 976, or 27.52 per cent, of the moths emerged. The remainder of the larvæ, 32.52 per cent, failed to transform to the adult stage.

TABLE XXVII.—*Band-record experiment. Codling moth larvæ collected at the Edwards orchard, Grand Junction, Colo., 1915.*

Date of collection, 1915.	Collection No.	Number of larvæ collected.	Total number of moths emerging, 1915.	Total number of moths emerging, 1916.	Per cent of— Moths emerging, 1915.	Moths emerging, 1916.	Dead individuals.
June 22	1	10	2	0	20.00	0	80.00
26	2	66	31	0	46.96	0	53.04
29	3	82	62	0	75.60	0	24.40
July 2	4	[1] 72	51	0	[4] 72.80	0	[4] 27.15
5	5	[2] 69	63	0	[4] 94.02	0	[4] 5.98
8	6	89	77	0	86.51	0	13.49
11	7	[3] 104	100	1	[4] 97.08	[4] 0.97	[4] 1.95
14	8	144	97	0	67.36	0	32.64
17	9	171	128	1	74.85	0.58	24.57
20	10	250	197	3	78.80	1.20	20.00
23	11	250	173	9	69.20	3.60	27.20
26	12	173	123	10	71.09	5.78	23.13
29	13	182	89	17	48.90	9.34	41.76
Aug. 1	14	155	80	37	51.61	23.87	24.52
4	15	167	58	55	34.73	32.94	32.33
7	16	198	49	85	24.74	42.97	32.29
10	17	153	24	43	15.68	28.10	56.22
13	18	162	9	50	5.55	30.86	63.59
16	19	135	4	100	2.96	74.07	22.97
19	20	126	0	63	0	50.00	50.00
22	21	127	0	78	0	61.41	38.59
25	22	117	0	88	0	75.21	24.79
28	23	123	0	81	0	65.85	34.15
31	24	70	0	44	0	62.85	37.15
Sept. 3	25	82	0	54	0	65.85	34.15
6	26	56	0	40	0	71.42	28.58
9	27	44	0	34	0	27.27	22.73
12	28	42	0	13	0	30.95	69.05
15	29	27	0	15	0	55.55	44.45
18	30	18	0	11	0	61.11	38.89
21	31	19	0	13	0	68.42	31.58
24	32	18	0	8	0	44.44	55.56
27	33	4	0	1	0	25.00	75.00
30	34	9	0	2	0	22.22	77.78
Oct. 3	35	10	0	7	0	70.00	30.00
6	36	0	0	0	0	0	0
9	37	7	0	4	0	57.14	42.86
12	38	6	0	1	0	16.66	83.34
15	39	1	0	1	0	100.00	0
18	40	1	0	1	0	100.00	0
21	41	0	0	0	0	0	0
24	42	5	0	1	0	20.00	80.00
27	43	3	0	3	0	1.00	0
30	44	0	0	0	0	0	0
Nov. 2	45	2	0	1	0	50.00	50.00
5	46	0	0	0	0	0	0
8	47	0	0	0	0	0	0
11	48	2	0	1	0	50.00	50.00
Total larvæ		3,551					
Total moths			1,417	976	[4] 39.96	[4] 27.52	[4] 32.52

[1] A larva killed in handling; 1 killed by predatory spider.
[2] 2 larvæ killed in handling.
[3] 1 larva killed in handling.
[4] All percentages based upon number of live larvæ collected.

The data in connection with the band studies made at the Hamilton orchard are shown in Table XXVIII and figure 14. The earliest collection was made June 28; the latest, October 21 following the final harvest of the fruit. A total of 4,183 larvæ was collected from which 2,092 moths, or 50.01 per cent, emerged in 1915. No moths issued during the season of 1915 from any larvæ that were collected in this orchard after August 19. For the percentage of moths issuing in 1915 from each collection of larvæ see figure 15. In the

spring of 1916, 869 moths issued, or 20.77 per cent of the total number of larvæ collected. The rest of the material, 29.22 per cent, did not reach the adult stage.

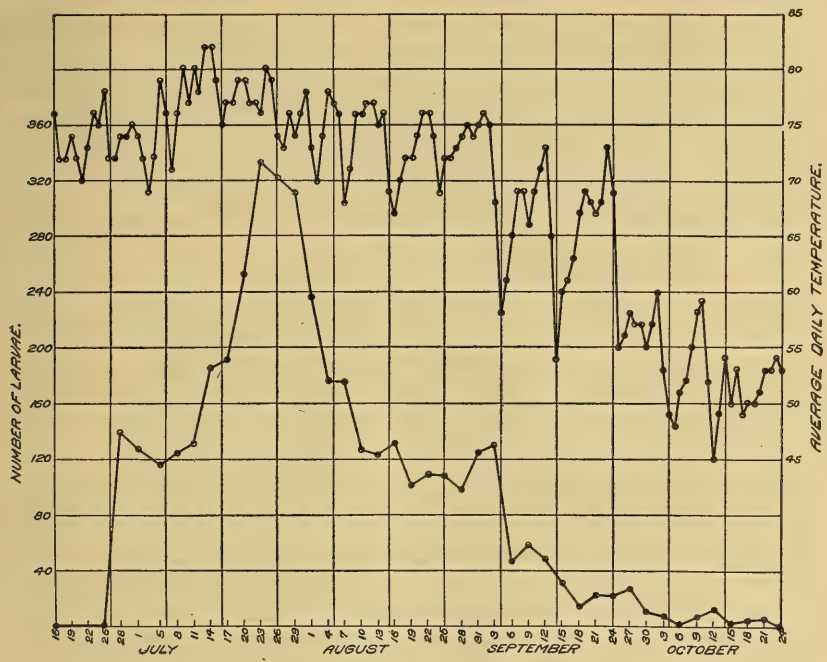


FIG. 14.—Number of larvæ of codling moth collected from banded trees, Hamilton orchard, Grand Junction, Colo., 1915.

Under field, or normal, conditions, there is a distinct overlapping of the larvæ of the first and second broods and of the second and third broods and similarly the moths of the first and second broods overlap. Hence with larvæ collected in the field it is impossible to know at all times to which brood the individuals belong. But with the insects reared at the insectary the brood identity

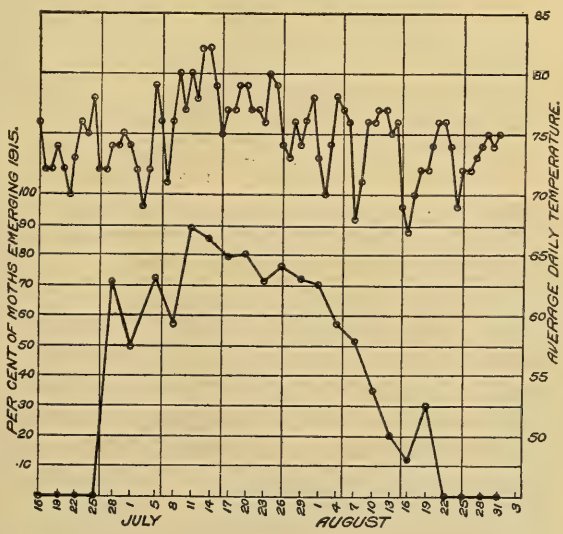


FIG. 15.—Percentage of codling moths emerging from band-collected material, Hamilton orchard, Grand Junction, Colo., 1915.

of each individual is definitely known, and this information aids in the establishment of the approximate limits of the broods as they occur in the field.

TABLE XXVIII.—*Band-record experiment. Codling moth larvæ collected at the Hamilton orchard, Grand Junction, Colo., 1915.*

Date of collection, 1915.	Collection No.	Number of larvæ collected.	Total number of moths emerging, 1915.	Total number of moths emerging, 1916.	Per cent of—		
					Moths emerging, 1915.	Moths emerging, 1916.	Dead individuals.
June 28	1	138	98	0	71.01	0	28.99
July 1	2	127	63	0	49.60	0	50.40
5	3	116	84	0	72.41	0	27.59
8	4	124	71	0	57.25	0	42.75
11	5	130	116	0	89.23	0	10.77
14	6	185	158	2	85.40	1.08	13.52
17	7	191	151	1	79.05	5.23	15.72
20	8	252	201	3	79.76	1.19	19.05
23	9	333	238	8	71.47	2.40	26.13
26	10	322	245	8	76.08	2.48	21.44
29	11	311	225	14	72.34	4.50	23.16
Aug. 1	12	235	165	13	70.21	5.53	24.26
4	13	176	101	25	57.38	14.20	28.42
7	14	176	89	53	50.56	30.11	19.33
10	15	127	44	31	34.64	24.40	40.96
13	16	123	24	37	19.51	30.08	50.41
16	17	131	16	51	12.21	38.93	48.86
19	18	101	3	54	29.70	53.46	16.84
22	19	109	0	54	0	49.54	50.46
25	20	108	0	82	0	75.92	24.08
28	21	98	0	81	0	82.65	17.35
31	22	123	0	76	0	61.78	38.22
Sept. 3	23	129	0	100	0	77.51	22.49
6	24	46	0	26	0	56.52	43.48
9	25	58	0	30	0	51.72.	48.28
12	26	48	0	22	0	45.83	54.17
15	27	31	0	16	0	51.16	48.39
18	28	14	0	11	0	78.57	21.43
21	29	23	0	15	0	65.21	34.79
24	30	22	0	13	0	59.09	40.91
27	31	27	0	18	0	66.66	33.34
30	32	11	0	8	0	72.72	27.28
Oct. 3	33	8	0	4	0	50.00	50.00
6	34	1	0	0	0	0	100.00
9	35	6	0	2	0	33.33	66.67
12	36	12	0	7	0	58.33	41.67
15	37	2	0	1	0	50.00	50.00
18	38	4	0	2	0	50.00	50.00
21	39	5	0	1	0	20.00	80.00
Total larvæ		4,183					
Total moths			2,092	869	50.01	20.77	29.22

In figure 16 is presented the total combined number of moths emerging daily from the larvæ collected in the Edwards and Hamilton orchards during the season of 1915. As will be observed therein, the moths began to emerge on July 9 and continued their emergence until September 8, except on September 4 and 6, when no moths issued. The maximum emergence, 152 moths, issued August 6. The total number of moths emerging from this combined material in 1915 was 3,509 and in the spring of 1916, 1,845, or 45.37 per cent and 23.86 per cent, respectively, of the total number of larvæ collected. The rest of the larvæ, 2380, or 30.77 per cent, died over winter or through injury as a result of handling or from other undetermined causes.

The life-history data obtained in 1915 are shown in diagram in figure 17.

SEASONAL-HISTORY STUDIES OF 1916.

During the season of 1916 the life-history studies of the codling moth were continued along the same lines as in the preceding year. In several instances, however, the work was elaborated somewhat, since the amount of material on hand was a little larger than in 1915. The biology of the codling moth in 1916 was quite similar to that of 1915, except that the second generation began somewhat earlier in the season. Full data on the third brood were obtained.

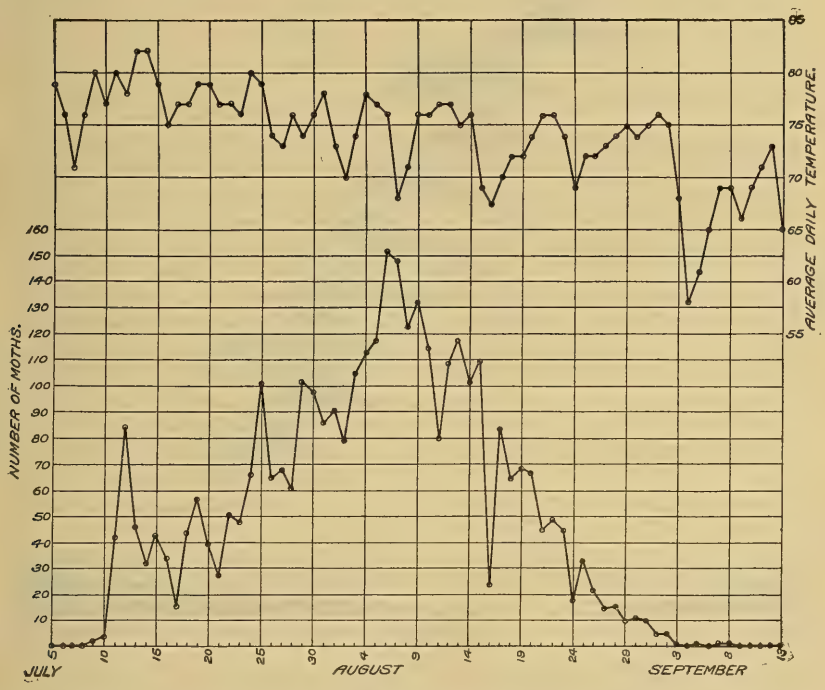


FIG. 16.—Time of emergence of codling moths from band-collected material, Hamilton and Edwards orchards, Grand Junction, Colo., 1915.

The blooming period of apple trees occurred in 1916 about the same time as in the previous year and, as in 1915, was followed by a little freezing weather. On the morning of June 30 the temperature dropped to 27° or 28° F. in some parts of the valley, while on the next morning the temperature was about 1° lower. At this time about 85 to 90 per cent of the blossoms had dropped in the orchards of the Fruitvale district. While some injury resulted from these freezes, it was not sufficient to cause a serious crop loss. Frost rings and pits, the latter being in the calyx cavity, developed in much of the fruit, however, and, as a result, the codling moth larvæ frequently entered the fruit through these frost pits.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—The daily observations of the time of pupation of the wintering larvæ are tabulated in Table XXIX and pre-

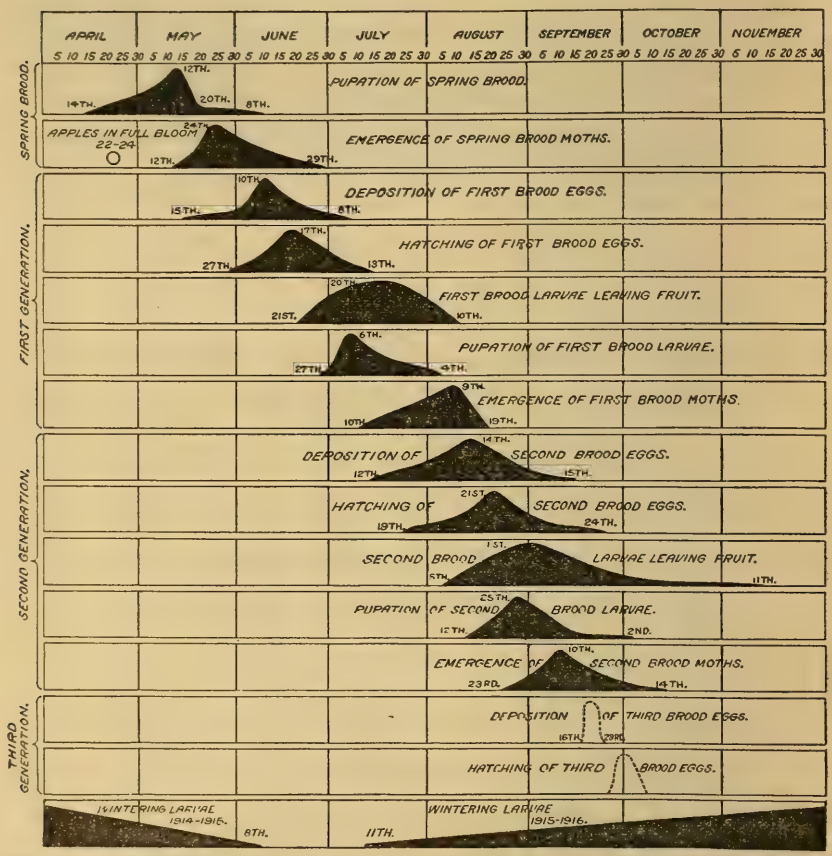


FIG. 17.—Diagram of life history of the codling moth in the Grand Valley of Colorado, 1915.

sented graphically in figure 18. Reference to this table will show that 508 larvæ were under observation and that the earliest pupation occurred April 16 and the latest June 12, the period thus covering about two months. The maximum pupation took place May 6, when 37 individuals pupated. On April 28, 36 larvæ transformed to pupæ, and if weather conditions had continued normal for the remainder of the month, it is probable that the maximum pupation would have occurred about May 1; but, as will be seen in the graph, the

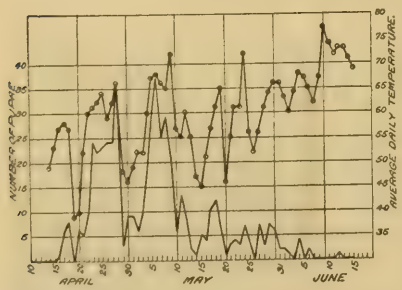


FIG. 18.—Time of pupation of spring brood of the codling moth, Grand Junction, Colo., 1916.

temperature dropped considerably, resulting in a check to the pupation activity.

TABLE XXIX.—*Time of pupation of wintering larvæ of the codling moth, Grand Junction, Colo., 1916.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
Apr. 16	1	Apr. 27	24	May 8	29	May 19	6	May 30	6
17	6	28	36	9	21	20	1	31	2
18	8	29	3	10	6	21	3	June 1	2
19	0	30	9	11	13	22	4	2	1
20	6	May 1	9	12	8	23	3	3	0
21	5	2	6	13	2	24	7	4	4
22	10	3	10	14	1	25	3	5	0
23	24	4	18	15	5	26	0	6	2
24	22	5	29	16	4	27	7	12	1
25	23	6	37	17	10	28	3		
26	24	7	25	18	12	29	7	Total	508

Length of the pupal stage.—The length of the pupal stage of the pupæ of the spring brood was computed from 390 individuals, beginning with five larvæ that pupated April 17 and ending with one that pupated June 12. The results of the observations are given in Table XXX, in which it will be noted that, as the season advanced with its higher temperatures, the pupal stage became shorter. Nearly 20 per cent of the pupæ were in the pupal stage 27 days, while the average length of this stage for all of the pupæ was 26.80 days with a range of from 13 to 36 days.

TABLE XXX.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Grand Junction, Colo., 1916.*

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.																				
		13	14	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	34	36
Apr. 17	5												1	2			1	1				
18	7												1			1	3	1	1			
20	4														3		1					
21	6														2	4						
22	8												1		5			1				1
23	18												1	2		1	12	2				
24	18															2	7	9				
25	17															2	12	3				
26	19														1	11	4	3				
27	18															3	3	5	6	1		
28	26														1		2	10	10	2	1	
29	3												1					2				
30	5									1						1	1	1	1			
May 1	7															6	1					
2	5														2	3						
3	5													1	3	1						
4	13												1	4	5	3						
5	25												1	6	15		2			1		
6	33											1		10	6	13	2	1				
7	20				1									1	12	6						
8	22													1	9	8	4					
9	13													1	3	7	2					
10	6														5		1					
11	12										1			3	4	4						
12	6													1	4	1						
13	1													1								
14	1													1								

TABLE XXX.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Grand Junction, Colo., 1916*—Continued.

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.																				
		13	14	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	34	36
May 15	4											3		1								
16	3										1	2										
17	7										4	2									1	
18	9									3	3	1	1	1								
19	4								1	1	2											
20	1									1												
21	2								2													
22	3							1	1		1											
23	3							2						1								
24	5					2	1		2													
25	2					1												1				
27	4					4																
28	2				1	1																
29	5			1	2	2																
30	6				6																	
31	1						1															
June 2	1				1																	
4	2		1	1																		
6	2		1	1																		
12	1	1																				
Pupæ....	390	1	2	3	11	10	2	3	6	6	12	9	8	37	80	77	58	40	18	4	2	1

	Days.
Average length of pupal stage	26.8
Maximum length of pupal stage	36
Minimum length of pupal stage	13

MOTHS OF THE SPRING BROOD.

Time of emergence.—The tabulated data of the time of emergence of 4,808 moths of the spring brood are given in Table XXXI. The first of these emerged May 10 and the emergence period continued until June 28, when the last moth of this brood issued. The emergence reached its maximum on May 24, on which day 552 moths appeared. On the preceding day, May 23, the next highest in number, 432 moths, issued. The retardation of emergence, as caused by adverse climatic factors on May 20, is readily seen by the marked decrease in emergence from 309 moths May 19 to 3 moths May 20. The daily rate of emergence is shown in figure 19.

TABLE XXXI.—*Time of emergence of codling moths of the spring brood, Grand Junction, Colo, 1916.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
May 10	3	May 21	13	June 1	169	June 11	74	June 21	1
11	10	22	368	2	80	12	58	22	5
12	21	23	432	3	146	13	42	23	1
13	49	24	552	4	150	14	43	24	3
14	8	25	151	5	120	15	29	25	2
15	4	26	135	6	97	16	26	26	1
16	39	27	160	7	45	17	17	27	0
17	36	28	274	8	86	18	17	28	1
18	162	29	247	9	79	19	11		
19	309	30	283	10	53	20	14	Total....	4,808
20	3	31	179						

Oviposition by moths of the spring brood.—The data obtained from the oviposition studies of 1,449 female moths confined in 123 cages with 1,292 male moths are presented in Table XXXII. The summarized figures give for the average number of days from the time of emergence to day of first oviposition 6.07, maximum 13 days, minimum 2 days; average number of days of oviposition 13.38, maxi-

FIG. 19.—Time of emergence of codling moths of the spring brood, Grand Junction, Colo., 1916.

mum 32 days, minimum 1 day; average number of days from the date of emergence to last oviposition 18.46, maximum 34 days, minimum 7 days.

Number of eggs per female moth.—In connection with the oviposition studies of moths of the spring brood, it was found that the average number of eggs per female moth was 11.34.

TABLE XXXII.—*Oviposition by codling moths of the spring brood in rearing cages, Grand Junction, Colo., 1916.*

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male.	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition.	From date of emergence to last oviposition.
1	20	10	10	May 13	May 21	June 4	76	8	15	22
2	5	3	2	May 14 May 15	.....	.....	1	.....	.....	.....
3	13	7	6	May 16	May 19	June 4	89	3	17	19
4	23	14	9	May 17	May 22	...do....	110	5	14	18
5	25	19	6	.do....	May 24	June 1	145	7	9	15
6	25	20	5	...do....	...do....	June 16	209	7	24	30
7	26	18	8	May 18	May 23	June 5	184	5	14	18
8	28	17	11	...do....	...do....	June 11	440	5	20	24
9	27	18	9	...do....	May 24	...do....	241	6	19	24
10	25	10	15	May 19	May 23	June 6	283	4	15	18
11	15	8	7	...do....	...do....	June 10	247	4	19	22
12	25	11	14	...do....	May 24	June 8	267	5	16	20
13	23	12	11	...do....	...do....	June 14	304	5	22	26
14	24	13	11	...do....	May 27	June 11	135	6	16	21
15	23	7	16	...do....	...do....	June 16	210	6	21	26
16	24	11	13	...do....	May 31	June 13	286	12	14	25
17	1	1	.....	May 20	.....	.....	0	.....	.....	.....
18	2	1	1	May 21	.....	.....	1	.....	.....	.....
19	22	11	11	May 22	May 26	June 11	229	4	17	20
20	25	8	17	...do....	...do....	June 16	202	4	22	25
21	21	13	8	...do....	May 27	June 14	214	5	19	23
22	24	14	10	...do....	...do....	June 17	138	5	22	26
23	16	4	12	...do....	May 28	June 14	186	6	18	23
24	25	10	15	...do....	May 29	June 11	79	7	14	20
25	25	7	18	...do....	...do....	June 16	186	7	19	25
26	25	11	14	...do....	May 30	June 9	86	8	11	18
27	24	11	13	May 23	May 26	June 12	189	3	18	20
28	26	14	12	...do....	May 27	June 9	258	4	14	17
29	20	5	15	...do....	...do....	June 17	322	4	22	25
30	25	10	15	...do....	May 29	June 11	198	6	14	19
31	23	12	11	...do....	...do....	...do....	254	6	14	19
32	25	14	11	...do....	...do....	June 15	172	6	18	23
33	23	9	14	...do....	...do....	...do....	244	6	18	23
34	25	14	11	...do....	May 31	June 11	154	8	12	19
35	16	4	12	...do....	June 3	June 17	44	11	15	25
36	24	11	13	May 24	May 29	June 12	179	5	15	19
37	25	8	17	...do....	May 30	June 5	11	6	7	12
38	25	11	14	...do....	...do....	June 8	40	6	10	15
39	24	7	17	...do....	...do....	June 12	45	6	14	19
40	20	13	7	...do....	May 31	June 16	12	7	17	23
41	25	12	13	...do....	...do....	June 18	50	7	19	25
42	24	13	11	...do....	June 1	June 15	156	8	15	22
43	24	11	13	...do....	June 2	June 8	49	9	7	15
44	25	11	14	...do....	June 3	June 17	63	10	15	24
45	25	12	13	...do....	June 6	...do....	108	13	12	24
46	25	9	16	...do....	...do....	June 6	1	13	1	13
47	20	14	6	...do....	.....	.....	7	.....	.....	.....
48	13	6	7	...do....	.....	.....	14	.....	.....	.....
49	25	11	14	May 25	June 4	June 17	247	10	14	23
50	24	11	13	...do....	June 5	June 11	44	11	7	17
51	25	14	11	...do....	...do....	June 16	226	11	12	22
52	11	7	4	...do....	June 7	June 13	78	13	7	19
53	23	12	11	May 26	May 31	June 20	182	5	21	25
54	25	12	13	...do....	June 1	June 16	83	6	16	21
55	14	4	10	...do....	June 3	June 17	68	8	15	22
56	24	10	14	...do....	June 5	June 18	141	10	14	23
57	20	12	8	May 27	May 30	June 6	91	3	8	10
58	25	8	17	...do....	June 3	June 16	63	7	14	20
59	25	12	13	...do....	June 4	June 13	17	8	10	17
60	19	9	10	...do....	June 8	...do....	97	12	6	17
61	27	8	19	May 28	May 31	June 14	57	3	15	17
62	25	14	11	...do....	...do....	July 1	19	3	32	34
63	22	10	12	...do....	June 1	June 9	126	4	9	12
64	24	8	16	...do....	June 2	June 17	97	5	16	20
65	24	10	14	...do....	June 3	June 25	241	6	23	28
66	27	11	16	...do....	June 5	June 9	53	8	5	12
67	27	12	15	May 29	June 2	June 15	194	4	14	17
68	25	11	14	...do....	...do....	June 17	132	4	16	19
69	13	5	8	...do....	June 5	...do....	83	7	13	19
70	25	14	11	...do....	June 6	...do....	206	8	12	19
71	25	13	12	...do....	June 8	June 20	66	10	13	22

TABLE XXXII.—*Oviposition by codling moths of the spring brood in rearing cages, Grand Junction, Colo., 1916*—Continued.

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male.	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition.	From date of emergence to last oviposition.
72	23	10	13	May 29	June 10	June 16	154	12	7	18
73	25	10	15	May 30	June 2	June 13	39	3	12	14
74	28	12	16	...do....	...do....	June 18	95	3	17	19
75	27	14	13	...do....	June 5	June 15	174	6	11	16
76	27	7	20	...do....	...do....	June 18	98	6	14	19
77	25	14	11	...do....	June 9	June 15	25	10	7	16
78	27	13	14	...do....	June 10	June 16	35	11	7	17
79	15	8	7	May 31	June 5	June 18	61	5	14	18
80	24	16	8	...do....	June 6	June 17	126	6	12	17
81	25	14	11	...do....	June 10	...do....	58	10	8	17
82	24	10	14	...do....	...do....	June 20	44	10	11	20
83	25	14	11	...do....	...do....	June 25	67	10	16	25
84	16	7	9	June 1	June 5	June 18	252	4	14	17
85	24	10	14	...do....	June 8	...do....	126	7	11	17
86	24	16	8	...do....	...do....	...do....	203	7	11	17
87	23	10	13	...do....	June 10	June 17	46	9	8	16
88	24	14	10	June 2	June 7	...do....	188	5	11	15
89	25	14	11	...do....	June 8	June 16	80	6	9	14
90	24	5	19	June 3	June 5	June 14	106	2	10	11
91	22	11	11	...do....	June 6	June 20	171	3	15	17
92	25	13	12	...do....	June 8	...do....	73	5	13	17
93	25	9	16	...do....	June 10	June 17	34	7	8	14
94	24	12	12	June 4	June 6	June 24	269	2	19	20
95	24	9	15	...do....	June 7	June 21	327	3	15	17
96	26	11	15	...do....	June 9	...do....	158	5	13	17
97	28	14	14	...do....	June 10	June 20	95	6	11	16
98	24	12	12	June 5	...do....	June 21	94	5	12	16
99	23	11	12	...do....	June 12	June 26	139	7	15	21
100	11	4	7	...do....	June 14	June 18	10	9	5	13
101	25	13	12	June 6	June 8	June 20	103	2	13	14
102	25	10	15	...do....	June 9	July 2	376	3	24	26
103	19	9	10	...do....	June 11	June 19	25	5	9	13
104	30	17	13	June 7	June 9	June 21	342	2	13	14
105	28	14	14	June 8	June 10	...do....	152	2	12	13
106	30	13	17	...do....	June 11	...do....	266	3	11	13
107	24	15	9	June 9	...do....	June 20	138	2	10	11
108	26	12	14	...do....	June 14	June 19	92	5	6	10
109	25	15	10	June 10	June 13	June 17	59	3	5	7
110	12	5	7	...do....	...do....	...do....	98	3	5	7
111	25	13	12	June 11	...do....	June 18	106	2	6	7
112	28	9	19	...do....	...do....	June 30	350	2	18	19
113	32	17	15	June 12	June 14	July 2	290	2	19	20
114	33	18	15	June 13	June 16	July 5	297	3	20	22
115	32	11	21	June 14	June 17	July 2	224	3	16	18
116	22	8	14	June 15	..do....	...do....	208	2	16	17
117	20	9	11	June 16	June 19	June 27	40	3	9	11
118	10	4	6	June 17	...do....	June 28	157	2	10	11
119	14	3	11	June 18	June 25	June 25	4	7	1	7
120	8	1	7	June 19	June 26	July 7	13	7	12	18
121	13	3	10	June 20	July 1	July 3	11	11	3	13
122	2	1	1	June 22	.....	.....	1	.....	.....	.....
123	4	1	3	June 23	July 2	July 7	7	9	6	14
Average							.....	6.07	13.38	18.46
Maximum							.....	13	32	34
Minimum							.....	2	1	7

Number of male moths..... 1,292
Number of female moths..... 1,449
Total number of moths..... 2,741
Total number of eggs..... 16,435
Average number of eggs per female moth..... 11.34

Length of life of moths.—As in the previous season, the dead moths were removed daily from the oviposition cages and the date of their death recorded. From these records the length of life of 2,738 moths was computed. As shown in Table XXXIII, the

average length of life of 1,281 male moths was 14.67 days, maximum 35 days, minimum 1 day; the average length of life of 1,457 female moths was 15.73 days, maximum 39 days, minimum 1 day.

TABLE XXXIII.—*Length of life of male and female codling moths of the spring brood in captivity: Summary of records of 2,738 individual moths, Grand Junction, Colo., 1916.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	9	1	6	15	64	15	96	29	7	29	13
2	7	2	4	16	56	16	96	30	12	30	6
3	6	3	6	17	59	17	88	31	3	31	4
4	14	4	11	18	50	18	70	32	6	32	6
5	29	5	12	19	43	19	68	33	5	33	4
6	46	6	18	20	64	20	94	34	3	34	2
7	64	7	41	21	48	21	70	35	2	35	3
8	79	8	40	22	39	22	41	36	0	36	0
9	48	9	73	23	27	23	40	37	0	37	0
10	88	10	75	24	30	24	27	38	0	38	1
11	78	11	77	25	18	25	23	39	0	39	1
12	56	12	93	26	27	26	23				
13	86	13	98	27	10	27	14	Total..	1,281	Total..	1,457
14	84	14	99	28	14	28	14				

Average length of life of male moths, 14.67 days; female moths, 15.73 days.
Maximum length of life of male moths, 35 days; female moths, 39 days.
Minimum length of life of male moths, 1 day; female moths, 1 day.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—In Table XXXIV and figure 20 it will be observed that the first eggs of the first brood were deposited May 19, and the last July 7, the period of deposition covering about 7 weeks. The eggs laid on the latter date, however, were infertile, but the single egg deposited July 5 completed its development and hatched on July 11. The largest number of eggs laid in one day was 883 on June 9, and this date was approximately the middle of the oviposition period.

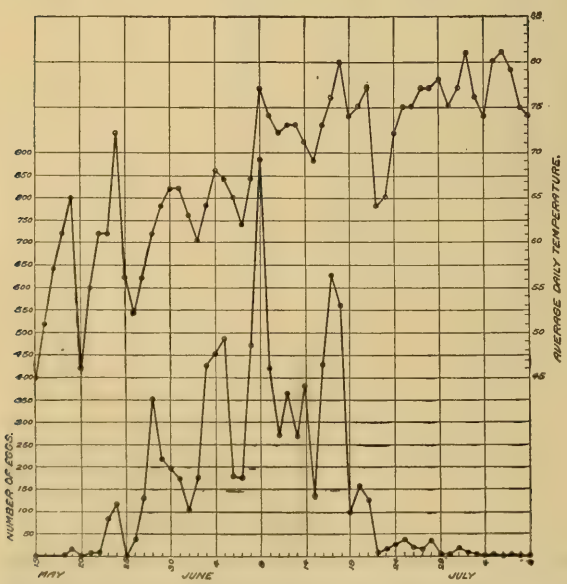


FIG. 20.—Time of deposition of eggs of the first brood of the codling moth, Grand Junction, Colo., 1916.

TABLE XXXIV.—*Time of deposition, length of incubation, and time of hatching of eggs of the first brood of the codling moth, Grand Junction, Colo., 1916.*

Observation No.	Number of eggs deposited.	Date—				Number of eggs hatched.	Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.		Red ring.	Black spot.	
							Days.	*Days.*	*Days.*
1	16	May 19	May 29	May 30	June 1	14	10	11	13
2					June 2	2			14
3	7	May 21	May 24	May 30	June 1	3	3	9	11
4					June 2	4			12
5	12	May 22	May 24	May 31	...do....	7	2	9	11
6					June 3	5			12
7	86	May 23	May 25	May 31	June 2	4	2	8	10
8					June 3	24			11
9					June 4	45			12
10	117	May 24	May 28	May 30	June 3	2	4	6	10
11					June 4	60			11
12					June 5	18			12
13					June 6	2			13
14	2	May 25	May 29	June 4	June 5	2	4	10	11
15	38	May 26	...do....	...do....	...do....	28	3	9	10
16					June 6	8			11
17	130	May 27	May 29	June 5	...do....	108	2	9	8
18					June 7	12			9
19	353	May 28	May 30	June 6	...do....	304	2	9	10
20					June 8	21			11
21	218	May 29	May 31	June 7	...do....	176	2	7	8
22					June 9	20			9
23	194	May 30	June 2	June 8	...do....	173	3	9	10
24					June 10	4			11
25	177	May 31	June 3	June 9	...do....	141	3	9	10
26					June 11	2			11
27	106	June 1	June 4	June 9	June 10	70	3	8	9
28					June 11	12			10
29					June 12	2			11
30	179	June 2	June 6	June 10	June 11	143	4	8	9
31					June 12	7			10
32	425	June 3	June 6	June 10	June 11	272	3	7	8
33					June 12	55			9
34	451	June 4	June 7	June 11	...do....	307	3	7	8
35					June 13	27			9
36	486	June 5	June 8	June 12	...do....	403	3	7	8
37	180	June 6	June 9	...do....	...do....	101	3	6	7
38					June 14	40			8
39					June 15	5			9
40	176	June 7	June 9	June 13	June 14	93	2	6	7
41					June 15	23			8
42	471	June 8	June 10	June 14	...do....	320	2	6	7
43					June 16	47			8
44	883	June 9	June 11	June 15	...do....	539	2	6	7
45					June 17	247			8
46					June 18	35			9
47	420	June 10	June 11	June 16	June 17	210	1	6	7
48					June 18	63			8
49	272	June 11	June 13	June 17	...do....	239	2	6	7
50	361	June 12	June 14	June 18	June 19	245	2	6	7
51					June 20	29			8
52	267	June 13	June 15	June 19	...do....	131	2	6	7
53	380	June 14	June 17	June 20	June 21	251	3	6	7
54	136	June 15	...do....	...do....	...do....	49	2	5	6
55					June 22	31			7
56	429	June 16	June 18	June 21	...do....	9	2	5	6
57					June 23	279			7
58					June 24	30			8
59	623	June 17	June 19	June 23	...do....	355	2	6	7
60					June 25	19			8
61	558	June 18	June 20	June 24	...do....	402	2	6	7
62					June 26	22			8
63	103	June 19	June 21	June 25	...do....	37	2	6	7
64					June 27	25			8
65					June 28	3			9
66	158	June 20	June 22	June 26	June 27	46	2	6	7
67	125	June 21	June 24	June 27	June 28	31	3	6	7
68					June 29	31			8
69	8	June 22	June 25	June 28	...do....	8	3	6	7
70	16	June 23	...do....	...do....	June 30	6	2	5	7
71	29	June 24	June 26	June 29	...do....	15	2	5	6
72					July 1	4			7
73					July 2	5			8
74	37	June 25	June 27	July 1	...do....	33	2	6	8
75	21	June 26	June 28	July 2	July 3	16	2	6	8
76	16	June 27	June 30	...do....	...do....	6	3	5	7

TABLE XXXIV.—*Time of deposition, length of incubation, and time of hatching of eggs of the first brood of the codling moth, Grand Junction, Colo., 1916*—Continued.

Observation No.	Number of eggs deposited.	Date—				Number of eggs hatched.	Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.		Red ring.	Black spot.	
							Days.	*Days.*	*Days.*
77	35	June 28	June 30	July 3	July 4	12	2	5	7
78	3	June 29	July 1	July 4	July 5	1	2	5	6
79	3	June 30	July 3	.....	.....	0	3	.....	0
80	15	July 1	...do....	July 6	July 7	9	2	5	6
81	8	July 2	July 4	July 7	July 8	5	2	5	6
82	.....	.....	.....	.....	July 9	2	.....	.....	7
83	4	July 3	.....	.....	.....	0	.....	.....	0
84	1	July 5	July 8	July 10	July 11	1	3	5	6
85	2	July 7	.....	.....	.....	0	.....	.....	0
Total.	8,774	.....	.....	.....	.....	6,597	.....	.....	.....
		Aver.				.....	2.62	6.68	7.32
		Max.				.....	10	11	14
		Min.				.....	1	5	6

Length of incubation.—The length of incubation and embryological changes of eggs of the first brood are given in Table XXXIV as follows: Average number of days from date of deposition to the appearance of the red ring 2.62 days, maximum 10 days, minimum 1 day; average appearance of the black spot from time of deposition 6.68 days, maximum 11 days, minimum 5 days; average incubation period 7.32 days, maximum 14 days, minimum 6 days.

LARVÆ OF THE FIRST BROOD.

Time of hatching.—The time of hatching of eggs of the first brood will be found in Table XXXIV. The first eggs of this brood hatched June 1; the last, July 11. Thus the period of incubation extended over one month, the maximum number hatching on June 16, or 15 days after the first larvæ appeared. The rate of hatching is shown diagrammatically in figure 21, in which it will be noted that the majority of the larvæ hatched about the middle of the hatching period.

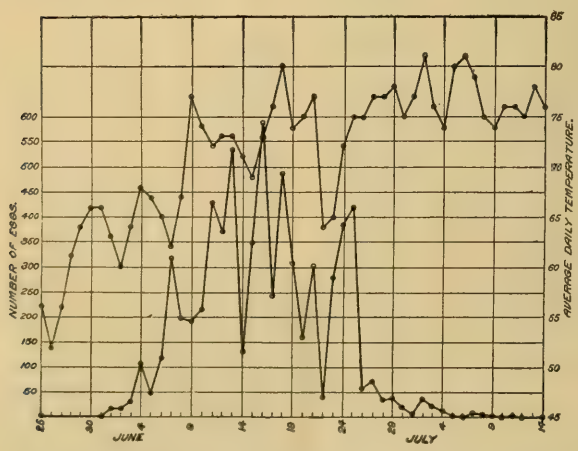


FIG. 21.—Time of hatching of eggs of the first brood of the codling moth, Grand Junction, Colo., 1916.

Length of the feeding period, stock-jar method.—The summarized account of the length of the feeding period of 817 larvæ of the first

brood, stock-jar method, will be found in Table XXXV. The first larvæ, as will be noted therein, entered the fruit June 8, while the last larvæ began feeding July 10. The average length of the feeding period was 20.19 days, maximum 42 days, and minimum 14 days.

Length of the feeding period, bagged-fruit method.—In Table XXXVI is given the length of the feeding period of 264 larvæ of the first brood according to the bagged-fruit method. In this study the first larvæ entered the fruit June 1, the last June 28. Reference to the summary of the table will show that the average feeding period was 21.10 days, maximum 29 days, and minimum 17 days.

TABLE XXXV.—*Length of feeding period of larvæ of the first brood of the codling moth, stock-jar method, Grand Junction, Colo., 1916.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																									
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	42
June 8	30	...	...	2	5	5	8	6	1	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	26	...	1	2	4	3	8	5	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	23	...	...	...	3	5	4	4	3	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	67	...	1	1	6	11	13	13	10	7	3	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	52	...	...	2	4	5	9	10	6	10	3	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	51	...	...	...	...	7	13	11	8	5	1	3	1	1	...	...	...	...	...	...	...	...	...	...	1	...	...
14	16	...	...	...	3	3	2	4	1	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	43	...	2	9	5	4	3	5	7	1	...	4	...	...	1	1	...	...	...	...	...	...	...	...	...	...	1
16	65	...	...	1	8	7	13	15	12	3	2	1	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...
17	43	...	1	2	7	7	3	11	3	4	1	...	2	1	...	...	...	...	...	...	...	1	...	...	...	...	...
18	33	...	3	4	6	3	4	4	2	...	1	2	...	2	...	...	...	...	1	...	...	...	...	...	...	1	...
19	22	...	...	...	3	6	3	1	2	2	3	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...
20	25	...	...	1	4	3	4	6	1	...	3	...	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...
21	38	...	...	3	1	4	8	5	6	4	2	...	1	2	...	...	1	1	...	...	...	...	...	...	...	...	...
22	38	1	...	3	7	5	8	7	1	3	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
23	16	...	1	...	1	2	...	4	1	3	...	1	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...
24	78	...	1	4	7	8	17	15	7	5	4	4	1	2	2	...	...	...	1	...	...	...	...	...	...	...	...
25	78	...	...	3	6	9	7	12	10	12	6	4	3	4	1	1	...	...	...	...	...	...	...	...	...	...	...
26	20	...	...	3	...	3	1	...	1	6	2	2	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...
27	24	...	...	5	3	6	3	...	3	1	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	2	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	5	...	...	1	...	1	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	2	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
July 2	2	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	1	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	10	...	...	...	...	...	...	1	2	1	1	...	2	...	...	...	...	...	...	1	...	1	1	...	...	...	...
5	1	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	2	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
10	3	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...
	817	1	10	48	83	107	139	140	90	75	37	31	14	16	8	4	1	2	2	1	1	2	1	1	1	1	1

	Days.
Average length of feeding period	20.19
Maximum length of feeding period	42
Minimum length of feeding period	14

TABLE XXXVI.—*Length of feeding period of codling-moth larvæ of the first brood, bagged-fruit method, Grand Junction, Colo., 1916.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.												
		17	18	19	20	21	22	23	24	25	26	27	28	29
June 1	1			1										
2	2			1						1				
3	1												1	
4	7		2		1		1	2		1				
5	6			1		4		1						
6	34		1	7		8	7	5	2	2		2		
7	27			3	10	5	3	2	4					
8	7		1			3	1		1	1				
9	2			1		1								
10	5				1	1	2	1						
11	10	1		3	1	1	2	1		1				
12	5		1			2			1			1		
13	23	1	2	10	2	2	4		1	1				
14	10			2	2		1	1		2	1			1
15	10			3	1	2		2			1		1	
16	15	1	1	3	7	2			1					
17	12	1		2	6		2					1		
18	1				1									
19	5		2	2		1								
20	14		1	2	2	5	2	2						
21	3					1	1	1						
22	2				1		1							
23	8			1	1	1	1	3	1					
24	16			3	2	3	1	3			2	2		
25	23	1	2	3	1	5	7	4						
26	7			2		2	1	2						
27	1		1											
28	7	2		4			1							
	264	7	14	54	39	49	38	30	11	9	4	6	2	1

	Days.
Average length of feeding period	21.10
Maximum length of feeding period	29
Minimum length of feeding period	17

Length of the cocooning period.—Table XXXVII gives the data for 761 larvæ, on the time which elapsed from the time each larva left the fruit until it pupated. Attention is drawn to the fact that 300, or nearly one-half, of these individuals formed their cocoons in 4 days, 195 in 5 days, and 89 in 6 days. The average cocooning period for all the larvæ was 5.53 days, the maximum 30 days, and the minimum 2 days.

TABLE XXXVII.—*Length of cocooning period, transforming codling moth larvæ of the first brood, Grand Junction, Colo., 1916.*

Larvæ left fruit.	Number of individuals.	Length of cocooning period in specified days, being the time from leaving the fruit to the time of pupation.																			Average days.	Maximum days.	Minimum days.
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	27	30		
June 20	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.00	5	5
21	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.00	4	4
22	2	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.00	5	3
24	6	...	1	4	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.00	5	3
25	14	...	2	10	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.14	7	3
26	19	...	2	7	5	2	...	...	2	...	...	...	...	...	...	...	1	...	...	...	...	5.58	17	3
27	30	...	4	11	6	5	2	...	1	1	...	...	...	...	...	...	...	...	...	...	...	4.97	10	4
28	40	...	...	17	7	9	5	...	...	...	1	...	...	...	...	...	...	...	...	...	1	5.83	30	4
29	34	...	...	10	10	4	4	1	1	1	1	...	...	1	...	...	1	...	...	...	...	6.21	17	4
30	35	...	...	13	11	4	3	...	2	2	...	...	...	...	...	...	...	...	...	...	...	5.43	10	4
July 1	47	...	1	23	9	4	...	2	3	1	1	1	...	...	1	...	...	1	...	...	...	5.81	18	3
2	52	...	4	24	13	1	3	2	...	1	1	1	...	...	...	1	...	1	...	...	...	5.44	18	3
3	51	...	1	23	5	10	6	2	3	...	...	...	1	...	...	...	...	...	...	...	...	5.45	13	3
4	43	...	3	15	15	5	1	...	1	...	...	...	...	1	1	1	...	...	...	...	...	5.47	16	3
5	35	...	...	12	13	4	3	...	1	...	1	1	...	...	...	...	...	...	...	...	...	5.43	12	4
6	37	1	2	8	12	6	2	2	...	1	2	...	1	...	...	...	...	...	...	...	...	5.70	13	2
7	51	...	...	19	17	6	1	...	1	2	1	3	1	...	...	...	...	...	...	...	...	5.75	13	4
8	21	...	...	9	6	1	2	1	...	...	...	1	1	...	...	...	...	...	...	...	...	5.67	13	4
9	29	...	2	13	3	3	2	2	...	1	1	1	...	...	...	...	...	...	1	...	...	5.97	19	3
10	26	...	2	12	4	5	1	...	...	...	1	...	1	...	...	...	...	...	...	...	...	5.19	13	3
11	21	...	...	4	10	...	2	2	1	...	1	...	1	...	...	...	...	...	...	...	...	6.14	13	4
12	28	...	1	11	9	3	2	1	1	...	...	...	...	...	...	...	...	...	...	...	...	5.04	9	3
13	33	...	...	18	11	2	...	1	...	...	...	...	...	...	...	...	...	1	...	...	...	5.00	18	4
14	25	...	...	5	7	7	1	...	1	1	...	2	...	...	...	1	...	...	...	...	...	6.52	16	4
15	19	...	...	7	6	4	...	...	...	...	...	...	...	...	...	1	...	...	...	1	...	6.58	27	4
16	13	...	1	4	4	1	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	5.31	8	3
17	14	1	4	6	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	4.00	8	2
18	10	...	3	3	...	2	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...	5.90	19	3
19	8	...	...	6	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	4.63	8	4
20	6	...	...	3	1	...	1	...	...	...	...	...	...	...	...	...	...	1	...	...	...	7.00	18	4
21	2	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.00	7	5
22	2	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.50	5	4
23	2	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.00	7	3
24	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.00	5	5
25	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.00	5	5
27	2	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.00	6	4
Total..	761	2	35	300	195	89	45	21	18	11	11	10	6	2	2	4	2	4	2	1	1	5.53	30	2

PUPÆ OF THE FIRST BROOD.

Time of pupation.—The larvæ of the first brood reared in the insectary began to pupate on June 25 and at this time 3 individuals transformed. The rate of pupation gradually increased until it reached its maximum on July 7, when 50 individuals pupated, as will be seen by reference to Table XXXVIII and figure 22. The last larva of this brood transformed to the pupal stage August 11. In all a total of 766 pupæ was recorded.

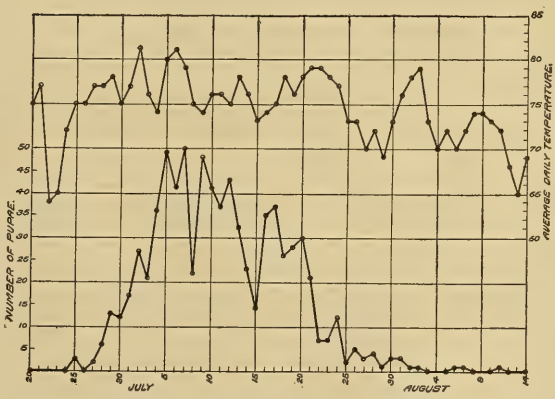


FIG. 22.—Time of pupation of first brood of the codling moth, Grand Junction, Colo., 1916.

TABLE XXXVIII.—*Time of pupation of transforming codling moth larvæ of the first brood, Grand Junction, Colo., 1916.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
June 25	3	July 5	49	July 14	23	July 23	7	Aug. 1	1
27	2	6	41	15	14	24	12	2	1
28	6	7	50	16	35	25	2	6	1
29	13	8	22	17	37	26	5	7	1
30	12	9	48	18	26	27	3	11	1
July 1	17	10	41	19	28	28	4		
2	27	11	37	20	30	29	1	Total..	766
3	21	12	43	21	21	30	3		
4	36	13	32	22	7	31	3		

Length of the pupal stage.—The data pertaining to the length of the pupal stage of first-brood pupæ began with the individuals that transformed June 25 and ended with the larva that pupated August 6. During this interval the variations in climatic conditions were not pronounced and, as a result, the range in the pupal period is not as great as with the spring-brood pupæ, it being from a minimum of 6 to a maximum of 19 days, with an average of 11.23 days. Out of a total of 638 pupæ, 284 had a pupal period of 12 days. For further details see Table XXXIX.

TABLE XXXIX.—*Length of the pupal stage of codling moth pupæ of the first brood, Grand Junction, Colo., 1916.*

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.											
		6	8	9	10	11	12	13	14	15	16	17	19
June 25	3				1		2						
27	2				1	1							
28	6				2	4							
29	12				1	7	4						
30	12				2	9	1						
July 1	17					8	8	1					
2	26			1	2	10	9	4					
3	20		1		2	5	9	2			1		
4	35		1		2	15	15	1	1				
5	46				2	8	22	14					
6	39				1	3	21	14					
7	49					7	17	23	2				
8	22					4	7	9	1		1		
9	47				2	13	22	9	1				
10	39				1	4	20	13	1				
11	36				1	6	20	9					
12	42				1	8	21	8	3				1
13	30					8	7	14	1				
14	21				2	4	11	4					
15	13				3	5	4	1					
16	34				3	8	15	6	2				
17	37				1	4	13	15	4				
18	25				1	2	9	7	6				
19	26					4	7	10	5				
20	29	1				1	5	14	8				
21	21						7	12	2				
22	7						1	5	1				
23	7						1	3	2	1			
24	12						2	3	4	3			
25	2								1	1			
26	4							3	1				
27	3						1	1	1				
28	4							2	1			1	
29	1						1						
30	3					1	1			1			
31	3						1		2				
Aug. 1	1								1				
2	1								1				
6	1							1					
	638	1	2	1	31	149	284	108	52	6	2	1	1

	Days.
Average length of the pupal stage	11.23
Maximum length of pupal stage	19
Minimum length of pupal stage	6

Moths of the First Brood.

Time of emergence.—As in the studies of 1915 (p. 24), a record was kept of the time of emergence of first-brood moths reared from insectary-bred material in order to determine the approximate limits of the brood. In Table XL it will be noted that 829 moths issued from July 5 to August 19, inclusive; the same data are presented graphically with temperatures in figure 23. Records were also taken of the time of emergence of the moths that issued from the larvæ collected every three days in the Hamilton and Edwards orchards. The moths that issued up to August 13, inclusive, were used for oviposition purposes in preference to those from the insectary-bred material, because their rate of emergence corresponded more closely to that which would have occurred in the field. These data are given in Table XLI and figure 24, and, as seen therein, the first moth emerged June 25. The rate of emergence, however, was very low until July 1, but on this date 17 moths issued.

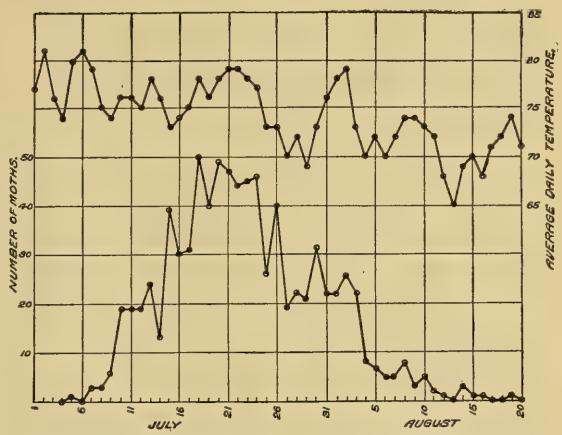


Fig. 23.—Time of emergence of codling moths of the first brood, insectary-bred material, Grand Junction, Colo., 1916.

The first moths of the second brood from insectary-bred material issued August 7, and the data indicate that from August 7 to 19 there was an overlapping of the moths of the first and second broods. Since there is no way of determining the brood to which the moths from field material belong, a date (Aug. 13) midway between that of the last emergence of the first-brood moths and the first emergence of the second-brood moths was taken as the dividing line between the two broods.

Table XL.—*Time of emergence of codling moths of the first brood, from material reared at the insectary, Grand Junction, Colo., 1916.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 5	1	July 15	39	July 24	46	Aug. 2	26	Aug. 11	2
7	3	16	30	25	26	3	22	12	1
8	3	17	31	26	40	4	8	14	3
9	6	18	50	27	19	5	7	15	1
10	19	19	40	28	22	6	5	16	1
11	19	20	49	29	21	7	5	19	1
12	19	21	47	30	31	8	8		
13	24	22	44	31	22	9	3	Total...	829
14	13	23	45	Aug. 1	22	10	5		

TABLE XLI.—*Time of emergence of codling moths of the first brood reared from field material, Grand Junction, Colo., 1916.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 25	1	July 6	25	July 17	40	July 28	165	Aug. 8	152
26	0	7	42	18	68	29	96	9	117
27	0	8	28	19	70	30	93	10	133
28	2	9	16	20	53	31	94	11	132
29	1	10	45	21	91	Aug. 1	110	12	77
30	5	11	41	22	125	2	111	13	72
July 1	17	12	72	23	76	3	95		
2	9	13	51	24	121	4	76		3,309
3	6	14	34	25	109	5	92		
4	30	15	59	26	83	6	111		
5	28	16	41	27	59	7	135		

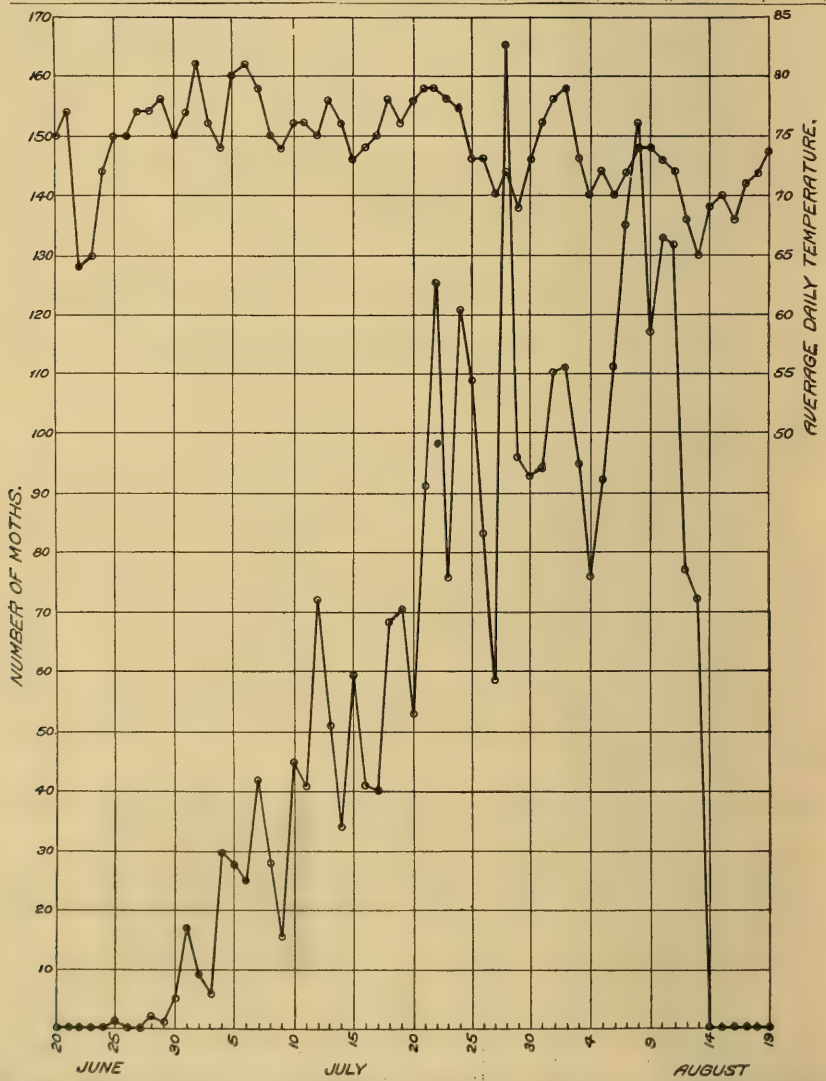


FIG. 24.—Time of emergence of codling moths of the first brood from band-collected material, Hamilton and Edwards orchards, Grand Junction, Colo., 1916.

Number of eggs per female moth.—The observations presented in Table XLII include 1,713 female moths which were confined with 1,596 male moths in 133 cages. These moths produced a total of 75,337 eggs, or an average of 43.98 eggs per female moth.

TABLE XLII.—*Oviposition by codling moths of the first brood in rearing cages, Grand Junction, Colo., 1916.*

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition.	From date of emergence to last oviposition.
.....	1	.....	.....	June 25	.....	.....	.....	.....	.....	.....
.....	2	.....	.....	June 28	.....	.....	.....	.....	.....	.....
.....	1	.....	.....	June 29	.....	.....	.....	.....	.....	.....
.....	5	.....	.....	June 30	.....	.....	.....	.....	.....	.....
.....	17	.....	.....	July 1	.....	.....	.....	.....	.....	.....
1	26	11	15	.....	July 3	July 15	812	.....	.....	.....
.....	9	.....	.....	July 2	.....	.....	.....	.....	.....	.....
.....	6	.....	.....	July 3	.....	.....	.....	.....	.....	.....
.....	11	.....	.....	July 4	.....	.....	.....	.....	.....	.....
2	26	9	17	.....	July 6	July 16	640	.....	.....	.....
3	19	10	9	July 4	...do....	July 17	315	2	12	13
4	28	14	14	July 5	...do....	July 16	322	1	11	11
5	25	6	19	July 6	July 8	...do....	753	2	9	10
6	21	13	8	July 7	...do....	July 24	398	1	17	17
7	21	14	7	...do....	July 11	July 18	134	4	8	11
8	28	14	14	July 8	...do....	July 23	541	3	13	15
9	16	4	12	July 9	...do....	July 28	256	2	18	19
10	22	8	14	July 10	...do....	July 24	161	1	14	14
11	23	15	8	...do....	July 12	July 23	479	2	12	13
12	21	9	12	July 11	...do....	July 16	125	1	5	5
13	20	15	5	...do....	July 13	July 20	219	2	8	9
14	26	14	12	July 12	...do....	July 28	352	1	16	16
15	20	9	11	...do....	July 15	July 23	516	3	9	11
16	26	10	16	...do....	...do....	July 24	204	3	10	12
17	25	12	13	July 13	July 14	July 27	612	1	14	14
18	26	13	13	...do....	July 16	July 28	357	3	13	15
19	34	17	17	July 14	July 15	July 26	1,020	1	12	12
20	33	12	21	July 15	July 17	July 30	900	2	14	15
21	26	12	14	...do....	July 21	July 27	85	6	7	12
22	26	10	16	July 16	July 17	Aug. 1	1,222	1	16	16
23	15	3	12	...do....	July 19	July 30	184	3	12	14
24	24	12	12	July 17	July 18	July 28	665	1	11	11
25	16	6	10	...do....	July 19	July 30	436	2	12	13
26	25	13	12	July 18	...do....	Aug. 1	748	1	14	14
27	25	16	9	...do....	July 20	...do....	654	2	13	14
28	18	5	13	...do....	...do....	...do....	1,088	2	13	14
29	21	11	10	July 19	...do....	July 30	555	1	11	11
30	25	10	15	...do....	July 22	July 28	420	3	7	9
31	24	14	10	...do....	...do....	July 30	579	3	9	11
32	26	12	14	July 20	...do....	July 31	794	2	10	11
33	27	8	19	...do....	July 23	July 28	341	3	6	8
34	24	7	17	July 21	July 22	July 31	281	1	10	10
35	21	5	16	...do....	...do....	Aug. 7	1,191	1	17	17
36	25	11	14	...do....	July 23	July 30	385	2	8	9
37	21	11	10	...do....	July 24	July 29	391	3	6	8
38	25	16	9	July 22	July 23	Aug. 4	791	1	13	13
39	24	14	10	...do....	July 24	Aug. 5	250	2	13	14
40	20	9	11	...do....	...do....	...do....	296	2	13	14
41	19	8	11	...do....	...do....	Aug. 7	536	2	15	16
42	24	12	12	...do....	...do....	Aug. 8	822	2	16	17
43	13	8	5	...do....	July 25	Aug. 4	228	3	11	13
44	26	14	12	July 23	July 24	Aug. 6	595	1	14	14
45	25	16	9	...do....	July 25	...do....	1,153	2	13	14
46	25	15	10	...do....	July 27	...do....	444	4	11	14
47	24	9	15	July 24	July 25	Aug. 4	1,013	1	11	11
48	25	11	14	...do....	...do....	Aug. 8	1,305	1	15	15
49	25	13	12	...do....	July 26	Aug. 9	1,017	2	15	16
50	23	8	15	...do....	...do....	Aug. 14	931	2	20	21
51	24	16	8	...do....	July 28	Aug. 4	540	4	8	11
52	28	16	12	July 25	July 27	Aug. 8	979	2	13	14
53	26	15	11	...do....	July 28	Aug. 7	802	3	11	13
54	27	11	16	...do....	...do....	...do....	1,423	3	11	13

TABLE XLII.—*Oviposition by codling moths of the first brood in rearing cages, Grand Junction, Colo., 1916*—Continued.

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition.	From date of emergence to last oviposition.
55	28	16	12	July 28	July 28	Aug. 8	1,065	3	12	14
56	28	18	10	July 26	...do....	...do....	709	2	12	13
67	27	14	13	...do....	...do....	...do....	1,018	2	12	13
58	28	10	18	...do....	...do....	Aug. 11	1,616	2	15	16
59	29	6	23	July 27	...do....	Aug. 15	915	1	19	19
60	30	13	17	...do....	July 29	Aug. 10	558	2	13	14
61	27	17	10	July 28	July 30	...do....	276	2	12	13
62	28	13	15	...do....	...do....	Aug. 13	381	2	15	16
63	28	20	8	...do....	July 31	Aug. 7	107	3	8	10
64	28	23	5	...do....	...do....	Aug. 8	341	3	9	11
65	28	13	15	...do....	...do....	Aug. 11	606	3	12	14
66	26	9	17	...do....	...do....	Aug. 12	1,016	3	13	15
67	24	11	13	July 29	...do....	...do....	601	2	13	14
68	22	10	12	...do....	...do....	Aug. 15	1,171	2	16	17
69	24	12	12	...do....	...do....	Aug. 16	277	2	17	18
70	26	20	6	...do....	Aug. 1	Aug. 11	432	3	11	13
71	20	13	7	July 30	July 31	...do....	408	1	12	12
72	24	15	9	...do....	Aug. 1	Aug. 14	344	2	14	15
73	24	14	10	...do....	...do....	...do....	427	2	14	15
74	25	8	17	...do....	Aug. 2	...do....	442	3	13	15
75	24	5	19	July 31	Aug. 1	Aug. 15	197	1	15	15
76	25	15	10	...do....	Aug. 2	Aug. 8	199	2	7	8
77	24	10	14	...do....	...do....	Aug. 11	468	2	10	11
78	21	9	12	...do....	Aug. 3	Aug. 12	455	3	10	12
79	28	13	15	Aug. 1	...do....	Aug. 16	565	2	14	15
80	26	15	11	...do....	...do....	Aug. 17	1,054	2	15	16
81	29	11	18	...do....	...do....	Aug. 21	991	2	19	20
82	27	12	15	...do....	...do....	...do....	1,484	2	19	20
83	29	6	23	Aug. 2	Aug. 4	Aug. 19	1,144	2	16	17
84	27	10	17	...do....	Aug. 5	Aug. 14	323	3	10	12
85	28	9	19	...do....	...do....	Aug. 19	415	3	15	17
86	27	10	17	...do....	Aug. 6	Aug. 13	562	4	8	11
87	25	11	14	Aug. 3	Aug. 5	Aug 11	608	2	4	8
88	25	14	11	...do....	...do....	Aug. 14	484	2	10	11
89	25	10	15	...do....	...do....	Aug. 16	680	2	12	13
90	20	10	10	...do....	Aug. 6	Aug. 18	373	3	13	15
91	22	5	17	Aug. 4	...do....	Aug. 17	457	2	12	13
92	22	12	10	...do....	...do....	Aug. 22	652	2	17	18
93	32	8	24	...do....	Aug. 7	Aug. 17	335	3	11	13
94	25	10	15	Aug. 5	Aug. 6	Aug. 22	1,043	1	17	17
95	25	6	19	...do....	...do....	Aug. 25	502	1	20	20
96	25	15	10	...do....	Aug. 7	...do....	468	2	19	20
97	17	15	2	...do....	Aug. 10	Aug. 10	3	5	1	5
98	26	7	19	Aug. 6	Aug. 7	Aug. 15	126	1	9	9
99	28	10	18	...do....	...do....	Aug. 17	950	1	11	11
100	28	16	12	...do....	Aug. 8	Aug. 21	575	2	14	15
101	29	10	19	...do....	...do....	Aug. 24	1,048	2	17	18
102	26	19	7	Aug. 7	...do....	Aug. 19	247	1	12	12
103	28	14	14	...do....	Aug. 9	Aug. 18	173	2	10	11
104	26	11	15	...do....	...do....	...do....	511	2	10	11
105	27	18	9	...do....	...do....	Aug. 22	479	2	14	15
106	28	12	16	...do....	Aug. 10	Aug. 24	143	3	15	17
107	27	17	10	Aug. 8	Aug. 9	Aug. 26	155	1	18	18
108	25	13	12	...do....	...do....	...do....	785	1	18	18
109	25	9	16	...do....	Aug. 10	Aug. 19	332	2	10	11
110	25	13	12	...do....	...do....	Aug. 20	234	2	11	12
111	25	16	9	...do....	...do....	Aug. 26	388	2	17	18
112	25	14	11	...do....	Aug. 11	Aug. 18	218	3	8	10
113	25	15	10	Aug. 9	Aug. 10	Aug. 23	517	1	14	14
114	25	10	15	...do....	...do....	...do....	733	1	14	14
115	25	11	14	...do....	Aug. 11	Aug. 22	710	2	12	13
116	24	9	15	...do....	...do....	Aug. 26	755	2	16	17
117	18	8	10	...do....	Aug. 14	...do....	377	5	13	17
118	27	11	16	Aug. 10	Aug. 12	Aug. 27	376	2	16	17
119	25	12	13	...do....	...do....	...do....	568	2	16	17
120	28	12	16	...do....	Aug. 14	Aug. 26	707	4	13	16
121	26	14	12	...do....	...do....	Aug. 29	624	4	16	19
122	27	14	13	...do....	...do....	Aug. 30	571	4	17	20
123	27	12	15	Aug. 11	Aug. 13	Aug. 27	703	2	15	16
124	25	13	12	...do....	...do....	Aug. 29	346	2	17	18
125	27	16	11	...do....	Aug. 14	Aug. 21	146	3	8	10
126	26	16	10	...do....	...do....	Aug. 22	445	3	9	11

TABLE XLII.—*Oviposition by codling moths of the first brood in rearing cages, Grand Junction, Colo., 1916*—Continued.

Cage No.	Number of moths.	Sex.		Date of—			Total number of eggs deposited.	Number of days—		
		Male.	Female.	Emergence of moths.	First oviposition.	Last oviposition.		Before oviposition.	Of oviposition.	From date of emergence to last oviposition.
127	27	14	13	Aug. 11	Aug. 14	Aug. 27	84	3	14	16
128	25	13	12	Aug. 12	...do....	Aug. 28	643	2	15	16
129	26	18	8	...do....	Aug. 15	Aug. 23	190	3	9	11
130	26	17	9	...do....	...do....	Aug. 26	406	3	12	14
131	25	17	8	Aug. 13	...do....	Aug. 29	146	2	15	16
132	25	12	13	...do....	...do....	...do....	735	2	15	16
133	22	11	11	...do....	Aug. 16	Aug. 31	609	3	16	18
Total...	3,309	1,596	1,713	.....	.....	.....	75,337	.....	.....	.....
Ave.								2.21	12.69	13.63
Max								5	20	20
Min								1	1	5

Average number of eggs per female moth, 43.98.

Time of oviposition.—As previously mentioned, the moths that issued up to August 13, inclusive, from the larvæ collected every three days from banded trees in the Hamilton and Edwards orchards, were employed for the oviposition studies.

It will be noted in the summary of this table that the average number of days from the date of emergence to the first oviposition was 2.21, maximum 5 days, minimum 1 day; the average number of days of oviposition was 12.69 days, maximum 20 days, minimum 1 day; the average number of days from the time of emergence to last oviposition was 13.63, maximum 20 days, minimum 5 days.

Length of life of moths.—A record was kept of the length of life of 3,231 moths of the first brood of which 1,561 were of the male sex and 1,670 of the female sex. According to the mortality data given in Table XLIII, the average length of life of the male moths was 13.12 days and of the female moths 12.20 days. The maximum length of life of the male moths was 38 days, female moths 26 days; minimum length of life of both the male and female moths 1 day.

TABLE XLIII.—*Length of life of male and female coaling moths of the first brood in captivity: Summary of records of 3,231 individual moths, Grand Junction, Colo., 1916.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	11	1	6	15	76	15	111	29	5	29	0
2	12	2	9	16	81	16	89	30	4	30	0
3	8	3	7	17	75	17	65	31	0	31	0
4	18	4	15	18	65	18	51	32	1	32	0
5	13	5	20	19	56	19	40	33	0	33	0
6	36	6	33	20	51	20	29	34	0	34	0
7	49	7	70	21	42	21	18	35	0	35	0
8	107	8	99	22	35	22	12	36	0	36	0
9	151	9	147	23	22	23	9	37	0	37	0
10	137	10	172	24	12	24	4	38	1	38	0
11	141	11	195	25	13	25	1				
12	124	12	156	26	5	26	1	Total..	1,561	Total..	1,670
13	102	13	169	27	4	27	0				
14	103	14	142	28	1	28	0				

Average length of life of male moths, 13.12 days; female moths, 12.20 days.
Maximum length of life of male moths, 38 days; female moths, 26 days.
Minimum length of life of male moths, 1 day; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Life cycle, stock-jar feeding method.—The summarized data giving the average length of each stage in the life cycle of the codling moth, first generation, are given in Table XLIV. These data are derived from the observations of 550 individuals reared by the stock-jar feeding method. By reference to this table it will be found that the average length of the incubation period was 7.67 days, larval feeding period 19.33 days, cocooning period 5.61 days, and pupal period 12.26 days. The average life cycle was 44.89 days and the average complete life cycle 47.10 days, obtained by adding to the life cycle 2.21 days, which is the average time that elapsed from the emergence of the moths to the deposition of the first egg.

Life cycle, bagged-fruit feeding method.—In Table XLV the results of rearing 188 individuals of the first generation from the egg to the adult stage, bagged-fruit method, are given. By reference to this table it will be seen that the average incubation period was 8.56 days, the larval feeding period 20.45 days, cocooning period 5.26 days, pupal period 11.86 days, average life cycle 46.37 days, and the average complete life cycle 48.58 days.

TABLE XLIV.—*Life cycle of the first generation of the codling moth, as observed by rearing, stock-jar feeding method, Grand Junction, Colo., 1916.*

Date of egg deposition.	Number of individuals.	Incubation.	Larvel feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 29	29	10	18.79	23	16	6.37	30	4	12.03	17	8	47.20	77	41
30	25	10	18.80	24	15	5.52	9	4	12.24	16	10	46.56	57	39
31	16	10	19.12	22	17	4.62	9	3	11.87	14	10	45.62	52	40
June 3	60	8	19.63	24	15	6.06	16	4	12.18	14	10	45.88	59	40
4	32	8	19.93	24	16	5.34	12	2	12.25	13	11	45.53	52	40
5	37	8	20.27	26	18	5.94	18	4	12.62	14	11	46.83	59	42
7	13	7	19.46	23	17	4.15	6	3	12.15	13	10	42.76	47	38
8	30	7	18.60	27	15	5.66	16	3	12.23	15	11	43.50	61	37
9	47	7	19.55	25	16	6.61	15	3	12.42	14	11	45.59	55	39
9	34	8	19.82	34	15	6.08	12	4	12.29	14	10	46.20	62	39
11	25	7	18.16	26	15	5.56	12	3	11.88	15	10	42.60	58	37
12	18	7	19.66	30	17	5.16	13	4	12.33	15	10	44.16	57	38
13	13	7	19.38	25	17	5.53	11	4	12.84	19	11	44.76	51	41
14	19	7	19.63	29	16	4.47	9	3	11.94	14	10	43.05	54	37
15	26	7	18.57	26	14	5.34	12	3	11.73	14	6	42.65	57	36
16	4	7	18.75	22	15	4.25	5	4	11.25	13	10	41.25	47	37
17	52	7	19.44	26	15	5.51	13	3	12.65	15	11	44.61	54	37
18	32	7	19.37	28	16	6.25	19	4	12.40	15	10	45.03	58	39
19	12	7	20.66	26	16	3.91	5	3	12.00	13	10	43.58	51	36
20	16	7	17.81	22	16	4.56	8	4	12.25	13	11	41.62	46	38
21	1	7	16.00	16	16	5.00	5	5	12.00	12	12	40.00	40	40
21	3	8	18.33	20	16	3.66	4	3	12.66	13	12	42.66	45	41
24	1	6	19.00	19	19	4.00	4	4	12.00	12	12	41.00	41	41
28	3	6	21.33	23	20	5.33	6	5	12.33	14	11	45.00	49	43
July 1	1	6	16.00	16	16	3.00	3	3	13.00	13	13	38.00	38	38
2	1	6	19.00	19	19	4.00	4	4	14.00	14	14	43.00	43	43
	550	7.67	19.33	34	14	5.61	30	2	12.26	19	6	44.89	77	36

[1] Add 2.21 days for complete life cycle.

TABLE XLV.—*Life cycle of the first generation of the codling moth, as observed by rearing, bagged-fruit feeding method, Grand Junction, Colo., 1916.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 19	1	13	19.00	19	19	5.00	5	5	10.00	10	10	47.00	47	47
22	2	11	22.00	25	19	4.00	4	4	11.50	12	11	49.50	51	46
24	6	11	20.66	23	18	3.66	5	3	11.00	12	10	46.33	50	44
26	6	10	21.00	23	19	4.33	5	3	11.16	12	11	46.50	49	44
27	28	10	21.46	27	18	5.25	11	3	11.42	14	8	48.14	58	42
28	24	10	21.25	24	19	6.62	18	3	12.00	14	9	49.87	66	44
29	7	10	21.71	25	18	4.71	7	3	11.42	13	10	47.85	52	45
30	1	10	19.00	19	19	4.00	4	4	12.00	12	12	45.00	45	45
31	5	10	21.60	23	20	4.20	5	4	11.40	12	10	47.20	50	44
June 3	9	8	20.55	25	17	4.44	6	4	11.66	13	10	44.66	49	41
4	4	8	21.75	27	18	4.50	5	4	12.75	13	12	47.00	52	44
5	22	8	20.04	25	17	4.95	15	3	11.90	14	11	44.90	57	40
7	6	7	21.33	25	19	5.50	8	3	12.00	13	10	45.83	50	42
8	6	7	19.83	21	19	5.00	6	4	12.16	13	12	44.00	46	42
9	9	7	19.77	24	17	4.66	7	2	11.88	13	11	43.33	49	39
9	8	8	19.62	22	17	6.50	19	4	11.62	13	11	45.75	62	40
12	5	7	19.00	21	18	4.20	5	4	12.20	13	12	42.40	44	41
13	7	7	20.00	23	18	7.00	18	4	11.70	13	10	45.71	60	39
14	1	7	22.00	22	22	4.00	4	4	13.00	13	13	46.00	46	46
15	1	7	20.00	20	20	4.00	4	4	10.00	10	10	41.00	41	41
16	4	7	21.50	24	19	4.75	6	4	12.50	14	11	45.75	49	41
17	4	7	20.25	21	19	5.00	6	4	12.25	14	11	44.50	47	43
18	11	7	20.72	23	17	7.27	19	3	12.45	14	10	47.45	62	38
19	3	7	21.66	23	21	4.66	5	4	13.33	14	13	46.66	48	46
20	1	7	18.00	18	18	5.00	5	5	12.00	12	12	42.00	42	42
21	7	7	18.85	22	17	3.57	5	2	13.14	15	12	42.59	49	40
	188	8.56	20.45	27	17	5.26	19	2	11.86	15	8	46.37	66	38

[1] Add 2.21 days for complete life cycle.

THE SECOND GENERATION.

Eggs of the Second Brood.

Time of deposition.—As given in Table XLVI, eggs of the second brood were deposited from July 3 to August 31, inclusive, and during this period 46,410 eggs were laid. These data were obtained by confining the moths that emerged from the larvæ collected in the

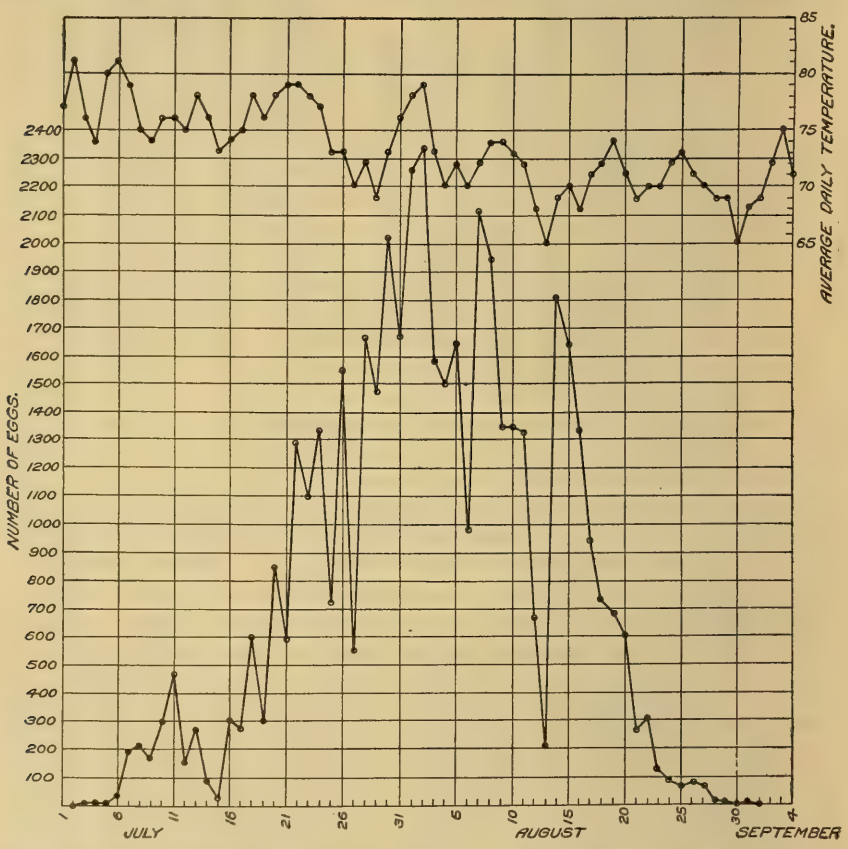


Fig. 25.—Time of deposition of eggs of the second brood of the codling moth, Grand Junction, Colo., 1916.

field, using all of the moths that issued up to August 13, inclusive. The greatest number of eggs laid on any one day was 2,333, and these were deposited on August 2. The time of egg deposition is shown graphically with average daily temperatures in figure 25.

TABLE XLVI.—*Time of deposition, length of incubation, and time of hatching of eggs of the second brood of the codling moth, Grand Junction, Colo., 1916.*

Observation No.	Number of eggs deposited.	Date— Deposited.	Date— Red ring.	Date— Black spot.	Date— Hatched.	Number of eggs hatched.	Appearance of— Red ring.	Appearance of— Black spot.	Incubation period.
							Days.	*Days.*	*Days.*
1	13	July 3	July 5	July 8	July 9	12	2	5	6
2	4	July 4	July 6	July 9	July 10	3	2	5	6
3	1	July 5	July 7	July 10	July 11	1	2	5	6
4	36	July 6	July 8	July 11	July 12	31	2	5	6
5	190	July 7	July 9	July 12	July 13	131	2	5	6
6					July 14	34			7
7					July 15	15			8
8	213	July 8	July 10	July 13	July 14	177	2	5	6
9					July 15	21			7
10	170	July 9	July 11	July 14	...do....	138	2	5	6
11					July 16	24			7
12	288	July 10	July 12	July 15	...do....	112	2	5	6
13					July 17	147			7
14					July 18	6			8
15	468	July 11	July 13	July 16	July 17	351	2	5	6
16					July 18	66			7
17	157	July 12	July 14	July 17	...do....	100	2	5	6
18					July 19	24			7
19	270	July 13	July 15	July 18	...do....	116	2	5	6
20					July 20	108			7
21	84	July 14	July 16	July 19	...do....	42	2	5	6
22					July 21	23			7
23	28	July 15	July 17	July 20	...do....	168	2	5	6
24					July 22	11			7
25					July 23	6			8
26	300	July 16	July 18	July 21	July 22	264	2	5	6
27					July 23	15			7
28	274	July 17	July 19	July 22	...do....	260	2	5	6
29	596	July 18	July 20	July 23	July 24	519	2	5	6
30	292	July 19	July 21	July 24	July 25	274	2	5	6
31	846	July 20	Juy 22	July 25	July 26	635	2	5	6
32					July 27	152			7
33	593	July 21	July 23	July 26	...do....	397	2	5	6
34					July 28	65			7
35					July 29	48			8
36	1,284	July 22	July 24	July 27	July 28	270	2	5	6
37					July 29	899			7
38	1,097	July 23	July 25	July 29	July 30	910	2	6	7
39					July 31	22			8
40	1,333	July 24	July 26	July 30	...do....	946	2	6	7
41					Aug. 1	187			8
42	722	July 25	July 27	July 31	...do....	541	2	6	7
43					Aug. 2	51			8
44	1,528	July 26	July 28	Aug. 1	...do....	1,375	2	6	7
45					Aug. 3	31			8
46	553	July 27	July 29	Aug. 2	...do....	431	2	6	7
47					Aug. 4	44			8
48	1,658	July 28	July 31	Aug. 3	...do....	1,542	3	6	7
49	1,471	July 29	...do....	...do....	...do....	338	2	5	6
50					Aug. 5	941			7
51					Aug. 6	118			8
52	2,019	July 30	Aug. 1	Aug. 4	Aug. 5	727	2	5	6
53					Aug. 6	1,171			7
54	1,674	July 31	Aug. 1	Aug. 5	...do....	268	1	5	6
55					Aug. 7	1,289			7
56	2,256	Aug. 1	Aug. 3	Aug. 7	Aug. 8	2,098	2	6	7
57	2,333	Aug. 2	Aug. 4	Aug. 8	Aug. 9	1,890	2	6	7
58	1,582	Aug. 3	Aug. 6	Aug. 9	Aug. 10	1,345	3	6	7
59	1,499	Aug. 4	...do....	Aug. 10	Aug. 11	1,364	2	6	7
60					Aug. 12	30			8
61	1,641	Aug. 5	Aug. 7	Aug. 11	...do....	1,313	2	6	7
62					Aug. 13	131			8
63					Aug. 14	115			9
64	980	Aug. 6	Aug. 8	Aug. 12	Aug. 13	245	2	6	7
65					Aug. 14	696			8
66	2,115	Aug. 7	Aug. 9	Aug. 13	...do....	338	2	6	7
67					Aug. 15	1,544			8
68					Aug. 16	64			9
69	1,944	Aug. 8	Aug. 10	Aug. 14	...do....	1,613	2	6	8
70					Aug. 17	117			9
71	1,347	Aug. 9	Aug. 11	Aug. 14	...do....	1,131	2	5	8
72	1,346	Aug. 10	Aug. 12	Aug. 17	Aug. 18	1,185	2	7	8
73					Aug. 19	67			9
74	1,322	Aug. 11	Aug. 14	Aug. 18	...do....	1,190	3	7	8
75	662	Aug. 12	...do....	Aug. 19	Aug. 20	549	2	7	8
76					Aug. 21	20			9

TABLE XLVI.—*Time of deposition, length of incubation, and time of hatching of eggs of the second brood of the codling moth, Grand Junction, Colo., 1916*—Continued.

Observation No.	Number of eggs deposited.	Date—				Number of eggs hatched.	Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.		Red ring.	Black spot.	
							Days.	*Days.*	*Days.*
77	212	Aug. 13	Aug. 16	Aug. 19	Aug. 20	155	3	6	7
78	1,806	Aug. 14	...do....	Aug. 20	Aug. 21	307	2	6	7
79	.....	.....	.....	.....	Aug. 22	1,300	.....	.....	8
80	.....	.....	.....	.....	Aug. 23	72	.....	.....	9
81	1,641	Aug. 15	Aug. 17	Aug. 22	...do....	1,411	2	7	8
82	.....	.....	.....	.....	Aug. 24	49	.....	.....	9
83	1,335	Aug. 16	Aug. 18	Aug. 22	Aug. 23	147	2	6	7
84	.....	.....	.....	.....	Aug. 24	975	.....	.....	8
85	.....	.....	.....	.....	Aug. 25	40	.....	.....	9
86	943	Aug. 17	Aug. 19	Aug. 24	...do....	811	2	7	8
87	723	Aug. 18	Aug. 20	Aug. 25	Aug. 26	578	2	7	8
88	689	Aug. 19	Aug. 21	...do....	...do....	145	2	6	7
89	.....	.....	.....	.....	Aug. 27	455	.....	.....	8
90	.....	.....	.....	.....	Aug. 28	34	.....	.....	9
91	613	Aug. 20	Aug. 22	Aug. 26	Aug. 27	80	2	6	7
92	.....	.....	.....	.....	Aug. 28	447	.....	.....	8
93	263	Aug. 21	Aug. 23	Aug. 27	...do....	8	2	6	7
94	.....	.....	.....	.....	Aug. 29	213	.....	.....	8
95	306	Aug. 22	Aug. 24	Aug. 29	Aug. 30	205	2	7	8
96	.....	.....	.....	.....	Aug. 31	46	.....	.....	9
97	132	Aug. 23	Aug. 25	Aug. 29	...do....	111	2	6	8
98	.....	.....	.....	.....	Sept. 1	11	.....	.....	9
99	89	Aug. 24	Aug. 26	Aug. 31	...do....	42	2	7	8
100	.....	.....	.....	.....	Sept. 2	35	.....	.....	9
101	.....	.....	.....	.....	Sept. 3	3	.....	.....	10
102	74	Aug. 25	Aug. 27	Sept. 1	Sept. 2	46	2	7	8
103	.....	.....	.....	.....	Sept. 3	21	.....	.....	9
104	80	Aug. 26	Aug. 28	Sept. 2	...do....	51	2	7	8
105	.....	.....	.....	.....	Sept. 4	10	.....	.....	9
106	65	Aug. 27	Aug. 29	Sept. 3	...do....	52	2	7	8
107	.....	.....	.....	.....	Sept. 5	9	.....	.....	9
108	18	Aug. 28	Aug. 30	Sept. 4	...do....	12	2	7	8
109	.....	.....	.....	.....	Sept. 6	2	.....	.....	9
110	9	Aug. 29	Sept. 1	Sept. 5	...do....	7	3	7	8
111	1	Aug. 30	...do....	...do....	...do....	1	2	6	7
112	12	Aug. 31	Sept. 2	Sept. 6	Sept. 8	10	2	6	8
Total.	46,410	.....	.....	.....	.....	43,624	.....	.....	.....
		Aver....	.....	.....	.....	.....	2.06	5.80	6.93
		Max....	.....	.....	.....	.....	3	7	10
		Min....	.....	.....	.....	.....	1	5	6

Length of incubation.—As previously noted, eggs of the second brood were deposited from July 3 to August 31, inclusive, and during this period observations of the length of incubation and embryological changes of these eggs were taken. The results in detail are shown in Table XLVI. From the data obtained it was found that the appearance of the red ring averaged 2.06 days from the time of deposition, maximum 3 days, minimum 1 day; the black spot appeared on an average of 5.80 days subsequent to the time of oviposition, maximum 7 days, minimum 5 days; the average total length of the incubation period was 6.93 days, maximum 10 days, minimum 6 days.

LARVÆ OF THE SECOND BROOD.

Time of hatching.—The hatching period of larvæ of the second brood is given in Table XLVI and, as appears therein, the first of these hatched July 9, while the last hatched September 8. In con-

nection with the control of the codling moth, the time of hatching of the second brood of eggs is of great importance, as is also the time when these eggs are hatching in largest numbers. It will be noted in this table and in figure 26 that the larvæ were appearing in greatest numbers during the middle of the hatching period. The maximum number of eggs, 2,098, hatched on August 8.

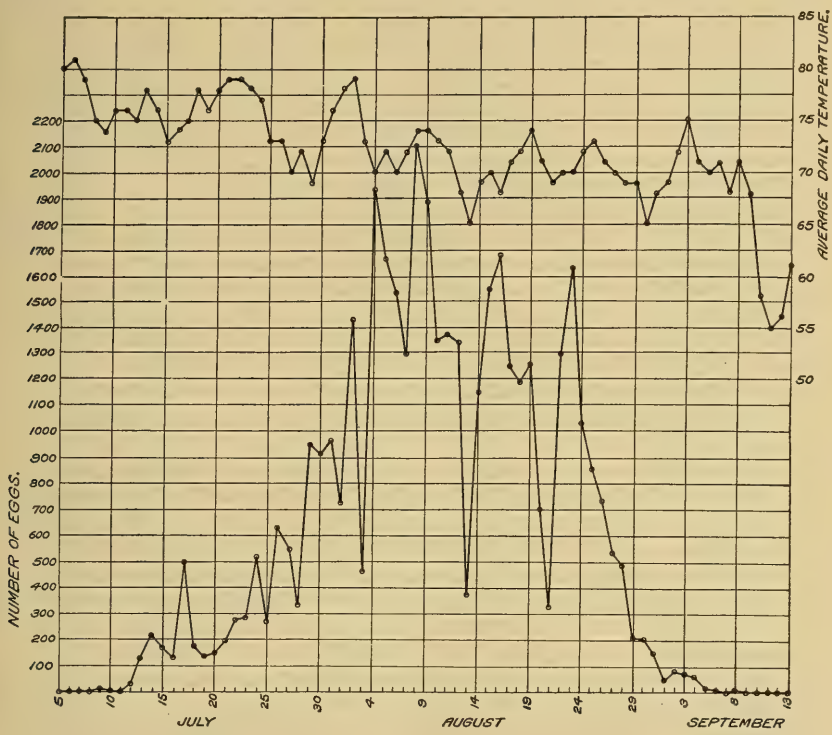


FIG. 26.—Time of hatching of eggs of the second brood of the codling moth, Grand Junction, Colo., 1916.

Length of the feeding period.—The data on the length of the feeding period of larvæ of the second brood, stock-jar method, are presented in detail in Table XLVII. The records are given for 2,569 larvæ, the dates of the entrance of which into the fruit and of leaving the fruit were observed. The summarized computations show that the average length of the feeding period of these larvæ was 28.61 days, maximum 70 days, minimum 14 days.

TABLE XLVII.—*Length of feeding period of codling moth larvæ of the second brood, stock-jar method, Grand Junction, Colo., 1916.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																										
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
July 9	40	2	8	3	13	6	4	1			1			1	1													
10	45	1	3	6	8	4	6	5	5	4	1				1	1												
11	51		2	3	7	7	1	8	4	9	4	2		2		1												
12	91	2	3	6	6	7	15	5	8	5	7	6	6	1	2	1	3	2	1		1	1		1	1	1		
13	71		2	1	3	3	11	11	5	6	5	7	2	4	3	1	3	1	1				1		1			
14	74		1	2	1	3	15	9	8	6	4	1	7	6		2	2	3	1			1				1		1
15	51		1	1		2	3	6	3	9	6	6	2	3		1	1	4	1	1						1		
16	76			2	2	3	1	12	8	11	6	5	5	3	5	2	5	1			1			2	1			
17	102				1	5	7	11	11	13	14	13	6	4	2	2	2	1	2	2		1	1		4			
18	83				2	1	6	7	6	15	7	8	10	4	1	1	2	3	2	1	1	1	1		1		1	
19	92					2	3	15	13	13	15	12	2	3	5	1	2	1	3	1				1				
20	56					3	3	5	8	7	4	4	3	1	2	3	2	3	2	1				1			1	
21	59				1		4	6	6	7	2	8	4	3	1	4	1	2		3		1						
22	77						2	8	7	7	7	16	5	5	7	2	1		2	1			1	2	1			
23	59						1	4	4	1	6	1	8	7	3	5		1	5		2	3			2	1	1	1
24	72						1	2	2	6	8	10	8	6	1	4	3	3	3	1	4	1	1		2		2	1
25	53							1	1	2	10	7	7	6	3	1	2		6	1		1	1			1		
26	79						1	3	1	6	8	14	3	12	7	5	5		2	2	2	1	3	1		1		
27	59						1	1	2	2	8	7	2	6	7	4	5	3	1	3	2	2	1	1				
28	37							1	1		4	9	5	3	3	1	3		3		1					1		
29	39									1	5	4	2	4	1	2	3	3	1	1	1		2	3		1		
30	48								5	3	6	4	6	2	2	2	4	1	1	1	3	2				1		1
31	47						1		2	4	1	2	5	4	5	4	1	5	3	3	2	2		1				
Aug. 1	34								1	1	2	2	4	6	2	2	2	1	5	1			1		2			1
2	46							1	1		3	4	6	5	7	4			1	3	1		1	1				1
3	41								1	3	2	7	7	3	3	4	3	4			2							
4	56							1		2	6	7	5	3	1	4	7	1	3	1	1	1	2	1	2			
5	43									2	2	3	1	3	5	4	6	3	4	1	1	1		1		1	1	2
6	46							1		2	1	4	6	2	3	4	4	4	1	1		1	2	2	1	4	1	
7	41									4		4	3	4	4	7	5		4	2	1		1			1		
8	44							1			1	3	7	5	1	5	2	6	3	1	1	2			2		1	
9	40											2	5	4	1	5	4	3	1	1	1	1	1	2	1		1	
10	30										2	1	5	2	1	1		3	1	1	1	1	3	2	1	2	1	
11	33										3	2	2	1	6		2	2			4	1	2		2	1		1
12	30									1	3	6	3	5		2	1	1	1			1				1		1
13	13							1		1	1	1		3			1	2	1	1						1		
14	12								1	1	1		1		1		1	2		2								
15	41							2	3	3	4	6	5	3		4	2		2		1	2	1			1	1	
16	29								1	3	3	5		2	1		3	1	1	1	1	1						
17	18								2	1	3	1	1	1	2	2			1				2		1		1	
18	28										1	1	2	2	2	1		4	1		1		3		1	1	1	
19	21										2					3	4	1	1	1	1	2		1			1	
20	29										2		1	1	2	3	1	2	4		4		1	1	2			
21	16											2			2	2	3	2	1	1			1					
22	18											1		1			1	2		1	1	2	2	1		1		
23	16											1				1	1	3	2		2			1		1		
24	31														1	1		1	1	1	3		1	2	2	1	2	1
25	30												1		1		1	1	3	4	1		2	2		1		1
26	27											1	2	1			2	3	1	1	1	2	1		1	1		1
27	32									1		1		1		1	3	3	4	2		2	2	1	1	2	1	
28	25														1			1	1	1	4	1	2			1	1	3
29	21												1	1	1		1		3	3	1	1		2	1	1		
30	14														1						1	1		2		2		
31	39													1		2	2	2	6	6		3	2	2	2	2	3	1
Sept. 1	46													1				3	5	1	2	2	5	2	1	2	4	1
2	46														1	1		4		1	2	1	1	2	2	2	5	
3	25														1	1	3				1	1		1			1	
4	14																	1		1	1		1	1		1	1	1
5	11																			2				2		2		
6	12																		1		1				1			
8	10																						1		1			
		5	20	24	44	46	86	128	120	162	181	211	166	151	113	114	115	103	103	64	62	47	52	46	39	44	32	19

TABLE XLVII.—*Length of feeding period of codling moth larvæ of the second brood, stock-jar method, Grand Junction, Colo., 1916*—Continued.

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																												
		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	70
July 11	51				1																									
16	76		1																											
18	83	1	1																											
20	56		1									1							1		1									
21	59					1											1			1				1			1			
22	77									1						1									1					
23	59			1		1																							1	
24	72						1											1								1				
25	53			1										1				1												
26	79											1												1						
27	59																					1								
28	37	1								1																				
29	39		2	1							1								1											
30	48	1			1	1														1										
31	47			1			1																							
Aug. 1	34	1																												
2	46		1	2		1				1	1									1										
3	41					1																						1		
4	56	2		1	2	1		1																						
5	43		1		1																									
6	46								1																1					
7	41		1																											
8	44	2			1																									
9	40	1		3						1					1							1								
10	30	1										1		1																
11	33	1			1			1					1																	
12	30	1							1				1									1								
14	12						1														1									
15	41														1															
16	29	1		1			2	1					1																	
18	28			1	3	1				1			1																	
19	21		1	1				2																						
20	29		1	2		1													1											
21	16						1	1																						
22	18	1					1			1						2														
23	16		2			1					1																			
24	31	1	2	2	2				1				2		1					1				2						
25	30	3	2	1	1		2							1									1		1					
26	27	2				2					1	1						2											1	
27	32	1	2		1							1		1						1										
28	25	1		3		1										3								1						
29	21		1	1										1	1								1							
30	14	1			1			1					1	3																
31	39		1					2				1	1																	
Sept. 1	46				2	1	2	2			1	4						2		2						1				
2	46	2	2		5	3					1						1	2	1			3	3	1						
3	25		2	2						2		1	1	1	1	1				1	1		1	1						1
4	14			1					1							1	1			1			1							
5	11							1				1		1						1	1									
6	12	1	1				3						1			1			1	1										
8	10			1					2		2				1	1			1											
	2,569	36	25	26	22	16	14	12	6	8	8	11	10	10	6	10	3	8	6	11	4	6	7	7	3	2	1	1	2	1

	Days.
Average length of feeding period	28.61
Maximum length of feeding period	70
Minimum length of feeding period	14

Length of cocooning period.—The data on the length of time consumed in constructing the cocoon by the transforming larvæ of the second brood are presented in Table XLVIII. By reference to this table it will be seen that the average cocooning period of 171 individuals was 4.80 days, the maximum 14, and the minimum 2 days.

TABLE XLVIII.—*Length of cocooning period of transforming codling moth larvæ of the second brood, Grand Junction, Colo., 1916.*

Larvæ left fruit.	Number of individuals.	Length of cocooning period in specified days, being the time from leaving the fruit to the time of pupation.											Ave.	Max.	Min.
		2	3	4	5	6	7	8	9	10	12	14			
													Days.	*Days.*	*Days.*
July 23	2	....	....	2	....	....	....	....	....	....	....	....	4.00	4	4
24	8	....	....	4	2	2	....	....	....	....	....	....	4.75	6	4
25	6	....	....	1	5	....	....	....	....	....	....	....	4.83	5	4
26	15	....	....	5	8	2	....	....	....	....	....	....	4.80	6	4
27	18	....	....	8	9	1	....	....	....	....	....	....	4.61	6	4
28	15	....	2	9	3	....	1	....	....	....	....	....	4.27	7	3
29	13	....	3	8	2	....	....	....	....	....	....	....	3.92	5	3
30	12	....	7	2	3	....	....	....	....	....	....	....	3.67	5	3
31	19	....	2	5	7	3	2	....	....	....	....	....	4.89	7	3
Aug. 1	10	....	1	5	2	2	....	....	....	....	....	....	4.50	6	3
2	17	....	....	5	5	5	1	....	....	....	....	1	5.65	14	4
3	8	....	....	4	1	2	....	1	....	....	....	....	5.13	8	4
4	6	....	....	4	2	....	....	....	....	....	....	....	4.33	5	4
5	7	1	....	2	3	1	....	....	....	....	....	....	4.43	6	2
6	3	....	....	1	2	....	....	....	....	....	....	....	4.67	5	4
7	2	....	....	2	....	....	....	....	....	....	....	....	4.00	4	4
8	4	....	....	....	1	1	1	....	....	....	1	....	7.50	12	5
9	1	....	....	....	....	1	....	....	....	....	....	....	6.00	6	6
10	1	....	....	....	....	....	....	....	....	1	....	....	10.00	10	10
11	1	....	....	....	....	....	....	....	1	....	....	....	9.00	9	9
13	2	....	....	....	....	....	1	....	....	1	....	....	8.50	10	7
14	1	....	....	....	1	....	....	....	....	....	....	....	5.00	5	5
Total...	171	1	15	67	56	20	6	1	1	2	1	1	4.80	14	2

PUPÆ OF THE SECOND BROOD.

Time of pupation.—The insectary reared larvæ of the second brood began pupating July 27, when 2 individuals transformed. The number of larvæ transforming daily increased up to August 1 and, as will be seen in Table XLIX and figure 27, 23 individuals pupated on this date. The last pupation occurred August 23.

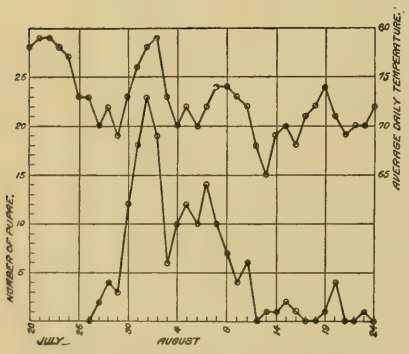


FIG. 27.—Time of pupation of second brood of the codling moth, Grand Junction, Colo., 1916.

Length of the pupal stage.—Data on the length of the pupal stage of 160 pupæ of the second brood were obtained. These observations are recorded in Table L, and, as shown therein, the observations included pupæ that transformed from July 27 to August 23. Owing to the fairly even climatic conditions during this period there was little difference in the length of the pupal stage, the range being from 11 to 16 days, with an average of 13.51 days.

TABLE XLIX.—*Time of pupation of transforming codling moth larvæ of the second brood, Grand Junction, Colo., 1916.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
July 27	2	Aug. 2	19	Aug. 8	10	Aug. 14	1	Aug. 20	4
28	4	3	6	9	7	15	2	21	0
29	3	4	10	10	4	16	1	22	0
30	12	5	12	11	6	17	0	23	1
31	18	6	10	12	0	18	0		
Aug. 1	23	7	14	13	1	19	1	Total....	171

TABLE L.—*Length of the pupal stage of codling moth pupæ of the second brood, Grand Junction, Colo., 1916.*

Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.						Date of pupation.	Number of individuals.	Length of the pupal stage in specified days.					
		11	12	13	14	15	16			11	12	13	14	15	16
July 27	1	1	....	....	....	....	....	Aug. 9	7	....	....	3	2	2	....
28	3	....	1	2	....	....	....	10	4	....	....	....	4	....	....
29	3	1	2	....	....	....	....	11	6	....	....	....	4	2	....
30	12	1	9	2	....	....	....	13	1	....	....	....	1	....	....
31	17	1	1	6	8	1	....	14	1	....	....	....	1	....	....
Aug. 1	21	1	2	10	6	1	1	15	2	....	1	....	....	....	1
2	17	....	....	7	3	6	1	16	1	....	....	1	....	....	....
3	6	....	....	2	4	....	....	19	1	....	....	....	1	....	....
4	9	....	....	4	4	1	....	20	3	....	....	1	1	1	....
5	12	....	1	5	4	2	....	23	1	....	....	....	1	....	....
6	9	....	1	5	3	....	....								
7	13	....	....	3	9	1	....	Pupæ...	160	5	19	52	60	20	4
8	10	....	1	1	4	3	1								

	Days.
Average length of pupal stage	13.51
Maximum length of pupal stage	16
Minimum length of pupal stage	11

MOTHS OF THE SECOND BROOD.

Time of emergence.—The time of emergence of 170 moths of the second brood is presented in Table LI. The first of these moths issued August 7, the last about one month later on September 6. The period of greatest emergence occurred from August 14 to August 21. As has already been referred to (p. 59), there is an overlapping of moths of the first and second broods from August 7, the time when the first moths of the second brood appeared, to August 19, when the last of the first brood of moths emerged. In figure 28 will be found a graph illustrating the time of emergence with average daily temperatures.

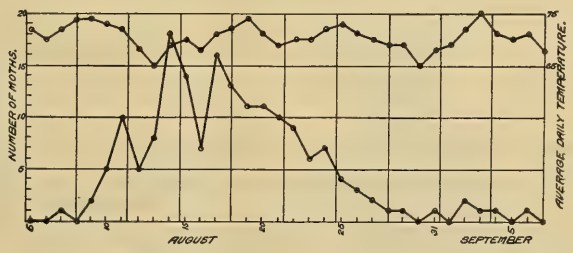


FIG. 28.—Time of emergence of codling moths of the second brood, Grand Junction, Colo., 1916.

TABLE LI.—*Time of emergence of codling moths of the second brood, from material reared at the insectary, Grand Junction, Colo., 1916.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
Aug. 7	1	Aug. 14	18	Aug. 20	11	Aug. 26	3	Sept. 3	1
9	2	15	14	21	10	27	2	4	1
10	5	16	7	22	9	28	1	6	1
11	10	17	16	23	6	29	1		
12	5	18	13	24	7	31	1	Total..	170
13	8	19	11	25	4	Sept. 2	2		

Number of eggs per female moth.—Included in this study were 86 female moths which were confined with 78 males in four cages. As will be noted in Table LII, 3,920 eggs were deposited, or 45.58 eggs per female moth.

Time of oviposition.—Since only a comparatively small number of moths of the second brood emerged each day, the maximum never exceeding 16, it was thought best, for purposes of uniform manipulation, to confine moths of several days' emergence in the same cage, as shown in Table LII. It was therefore impossible to obtain accurately the length of life of these moths and the period before, of, and after oviposition. It will be noted, however, by reference to this table and Table LIV, that the first oviposition by these moths occurred August 12, three days after the first female moth emerged. The last female died September 28, 7 days after the last egg was deposited.

TABLE LII.—*Oviposition by codling moths of the second brood in rearing cages, Grand Junction, Colo., 1916.*

Cage No.	Number of moths.	Date of emergence of moths.	Sex of moths. Male.	Sex of moths. Female.	Total number of eggs deposited.	Cage No.	Number of moths.	Date of emergence of moths.	Sex of moths. Male.	Sex of moths. Female.	Total number of eggs deposited.
1	1	Aug. 7	20	25	1,631	4	9	Aug. 22	21	18	571
	2	Aug. 9					6	Aug. 23			
	5	Aug. 10					7	Aug. 24			
	9	Aug. 11					4	Aug. 25			
	5	Aug. 12					3	Aug. 26			
	7	Aug. 13					2	Aug. 27			
	16	Aug. 14					1	Aug. 28			
2	14	Aug. 15	26	23	1,627		1	Aug. 29			
	6	Aug. 16					1	Aug. 31			
	16	Aug. 17					2	Sept. 2			
	13	Aug. 18					1	Sept. 3			
3	11	Aug. 19	11	20	91		1	Sept. 4			
	10	Aug. 20					1	Sept. 6			
	10	Aug. 21									
						Total...	164	.....	78	86	3,920

Average number of eggs per female, 45.58.

Length of life of moths.—As noted in the preceding paragraph, it was impossible to obtain accurate data on the length of life of the moths of the second brood, since the moths of several days' emergence

were confined in the same cage. However, one moth, a male, lived until September 30, 24 days after the last moth emerged. The last female died September 28, 22 days after the last moth emerged.

Life Cycle of the Second Generation.

The data on the life cycle of the second generation, as given in Table LIII, include 161 individuals. The summary of the records gives an average for the incubation period of 6.01 days, larval feeding period 18.08 days, cocooning period 4.78 days, pupal period 13.52 days, and life cycle 42.40 days. To determine the length of the complete life cycle of this generation for 1916, approximately 3 days should be added to these figures, since as noted in a previous paragraph headed "Time of oviposition," 3 days elapsed between the date of emergence of the first female moth and the date the first egg was deposited.

Table LIII.—*Life cycle of the second generation of the codling moth, as observed by rearing, stock-jar feeding method, Grand Junction, Colo., 1916.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
July 3	22	6	16.45	19	14	5.00	7	4	13.04	15	11	40.50	46	35
4	20	6	17.00	21	14	4.60	6	3	13.25	16	11	40.85	46	36
5	24	6	19.00	24	15	4.79	6	4	14.12	16	12	43.91	50	37
6	34	6	17.85	25	14	4.35	7	3	13.38	16	11	41.58	51	36
7	12	6	18.16	23	15	4.58	6	3	13.50	15	12	42.25	49	36
8	17	6	18.64	21	15	4.64	8	3	13.29	15	12	42.58	48	36
9	7	6	18.00	21	15	5.85	14	3	13.57	14	13	43.42	51	37
10	9	6	18.44	20	16	4.00	5	2	13.77	15	13	42.22	45	39
11	5	6	20.20	22	18	5.20	7	4	13.40	14	12	44.80	47	41
12	3	6	19.66	23	17	6.00	10	4	14.33	15	14	46.00	54	41
13	1	6	20.00	20	20	6.00	6	6	14.00	14	14	46.00	46	46
13	2	7	21.00	24	18	5.50	7	4	13.50	14	13	47.00	51	43
15	2	6	18.00	19	17	5.00	6	4	15.50	16	15	44.50	47	42
16	2	6	21.00	22	20	9.50	10	9	14.00	14	14	50.50	52	49
20	1	6	19.00	19	19	5.00	5	5	14.00	14	14	44.00	44	44
	161	6.01	18.08	25	14	4.78	14	2	13.52	16	11	42.40	54	35

THE THIRD GENERATION.

Eggs of the Third Brood.

Time of deposition.—The moths of the second brood commenced to deposit third-brood eggs on August 12 and on September 10 laid the last egg that fully developed. One egg was laid much later, September 21, but this failed to reach maturity. The largest number of eggs laid in any one day, 223, was deposited on August 27. For further details of the time of oviposition see Table LIV and figure 29.

TABLE LIV.—*Time of deposition, length of incubation, and time of hatching of eggs of the third brood of the codling moth, Grand Junction, Colo., 1916.*

Observation No.	Number of eggs.	Date—				Appearance of—		Incubation period.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.	
						Days.	*Days.*	*Days.*
1	49	Aug. 12	Aug. 17	Aug. 19	Aug. 20	5	7	8
2	2	...do...	.....	.....	Aug. 21	.....	.....	9
3	3	Aug. 13	Aug. 15	Aug. 19	Aug. 20	2	6	7
4	31	...do...	.....	.....	Aug. 21	.....	.....	8
5	15	Aug. 14	Aug. 16	Aug. 20	...do...	2	6	7
6	138	...do...	.....	.....	Aug. 22	.....	.....	8
7	26	Aug. 15	Aug. 17	Aug. 21	...do...	2	6	7
8	117	...do...	.....	.....	Aug. 23	.....	.....	8
9	21	Aug. 16	Aug. 18	Aug. 22	...do...	2	6	7
10	82	...do...	.....	.....	Aug. 24	.....	.....	8
11	3	...do...	.....	.....	Aug. 25	.....	.....	9
12	34	Aug. 17	Aug. 19	Aug. 23	Aug. 24	2	6	7
13	6	...do...	.....	.....	Aug. 25	.....	.....	8
14	2	...do...	.....	.....	Aug. 26	.....	.....	9
15	89	Aug. 18	Aug. 20	Aug. 24	Aug. 25	2	6	7
16	68	...do...	.....	.....	Aug. 26	.....	.....	8
17	79	Aug. 19	Aug. 21	Aug. 25	...do...	2	6	7
18	77	...do...	.....	.....	Aug. 27	.....	.....	8
19	98	Aug. 20	Aug. 22	Aug. 26	...do...	2	6	7
20	82	...do...	.....	.....	Aug. 28	.....	.....	8
21	80	Aug. 21	Aug. 23	Aug. 27	...do...	2	6	7
22	16	...do...	.....	.....	Aug. 29	.....	.....	8
23	63	Aug. 22	Aug. 24	Aug. 28	...do...	2	6	7
24	27	...do...	.....	.....	Aug. 30	.....	.....	8
25	84	Aug. 23	Aug. 25	Aug. 29	Aug. 31	2	6	8
26	15	...do...	.....	.....	Sept. 1	.....	.....	9
27	68	Aug. 24	Aug. 26	Aug. 31	...do...	2	7	8
28	5	Aug. 25	Aug. 27	...do...	...do...	2	6	7
29	129	...do...	.....	.....	Sept. 2	.....	.....	8
30	16	...do...	.....	.....	Sept. 3	.....	.....	9
31	107	Aug. 26	Aug. 28	Sept. 2	...do...	2	7	8
32	7	...do...	.....	.....	Sept. 4	.....	.....	9
33	150	Aug. 27	Aug. 31	Sept. 3	...do...	4	7	8
34	71	...do...	.....	.....	Sept. 5	.....	.....	9
35	2	...do...	.....	.....	Sept. 6	.....	.....	10
36	31	Aug. 28	Aug. 31	Sept. 3	Sept. 4	3	6	7
37	2	...do...	.....	.....	Sept. 5	.....	.....	8
38	2	Aug. 29	Sept. 1	Sept. 4	...do...	3	6	7
39	51	...do...	.....	.....	Sept. 6	.....	.....	8
40	20	Aug. 30	Sept. 2	Sept. 5	...do...	3	6	7
41	7	...do...	.....	.....	Sept. 7	.....	.....	8
42	7	Aug. 31	Sept. 3	Sept. 6	...do...	3	6	7
43	11	...do...	.....	.....	Sept. 8	.....	.....	8
44	3	...do...	.....	.....	Sept. 10	.....	.....	10
45	3	Sept. 1	Sept. 4	Sept. 7	Sept. 8	3	6	7
46	5	...do...	.....	.....	Sept. 9	.....	.....	8
47	1	Sept. 3	.....	Sept. 10	Sept. 11	.....	7	8
48	1	...do...	.....	.....	Sept. 12	.....	.....	9
49	1	Sept. 4	.....	Sept. 12	Sept. 14	.....	8	10
50	*5	Sept. 5	.....	.....	.....	.....	.....	.....
51	*1	Sept. 7	.....	.....	.....	.....	.....	.....
52	1	Sept. 10	Sept. 12	Sept. 19	Sept. 21	2	9	11
53	*1	Sept. 21	.....	.....	.....	.....	.....	.....
Av.	.....	.....	.....	.....	.....	2.49	6.36	7.77
Max	.....	.....	.....	.....	.....	5	9	11
Min.	.....	.....	.....	.....	.....	2	6	7

* Eggs not included in averages, due to failure to develop fully.

Length of incubation.—The tabulated data of the embryological changes and length of the incubation of eggs of the third brood are given in Table LIV. From these data it was found that the average number of days from the date of deposition to the appearance of the red ring was 2.49 days, maximum 5 days, and minimum 2 days; the average number of days from the time of deposition

to the appearance of the black spot was 6.36 days, maximum 9 days, and minimum 6 days; the average incubation period was 7.77 days, maximum 11 days, and minimum 7 days.

FIG. 29.—Time of deposition of third-brood eggs of the codling moth, Grand Junction, Colo., 1916.

LARVÆ OF THE THIRD BROOD.

Time of hatching.—The larvæ of the third brood commenced to hatch August 20, as will be noted in Table LIV and figure 30. Hatching continued daily, with some exceptions, up to September 21, the period thus having a duration of about one month. The larvæ were hatching in maximum numbers on September 4, and on this date 188 hatched. A large proportion of the eggs, however, hatched previous to this, namely from August 22 to 29.

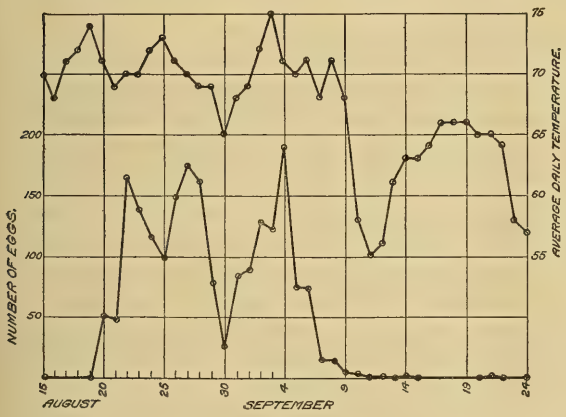


FIG. 30.—Time of hatching of third-brood eggs of the codling moth, Grand Junction, Colo., 1916.

Length of the feeding period.—The study of the feeding period of larvæ of the third brood, stock-jar method, included 331 larvæ. The first larvæ to hatch entered the fruit August 20, while the last larvæ entered the fruit September 21. None of the larvæ that entered the fruit after September 11 reached maturity. It will be noted in Table LV that the average feeding period of the larvæ under observation was 37.55 days, maximum 68 days, and minimum 20 days.

TABLE LV.—*Length of feeding period of codling moth larvæ of the third brood, stock-jar method, Grand Junction, Colo., 1916.*

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																			
		20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Aug. 20	27	3	1						3	1		7		1		1	2	1	2	1	
21	16		1	2	2	3		1	1		3		1			1					
22	23		1		2	1		1		5	1	1			1					2	
23	16								3	1	2		1	1	2			1			2
24	9							2	1	2			3								
25	17						1	2	1	1		2	1	2	1	1			3		
26	23			1			1				1		1	1			3	3			1
27	19						2		1	1		2	1	1		1	3				1
28	16									1	2	1				2	1		1	2	
29	18					1				2		2		1	1	1	4		1	1	
30	13												1	1			2	2			
31	29						2				1	1	4		2	3	1	1	3	4	1
Sept. 1	23							1			1	1	1	1	1	5	1	1	4		
2	27									1	3	1	2	1		3	3	2			
3	17									2				1	2	1	3	1	2	1	
4	9														1		1			1	
5	3																				1
6	14																1			2	2
7	8																			2	4
8	3																				
11	1																				
Larvæ..	331	3	3	3	4	5	6	7	10	17	14	18	16	11	11	19	25	12	16	16	12

Date of entering fruit.	Number of individuals.	Length of feeding period in specified days.																			
		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	58	59	63	67	68
Aug. 20	27						1	1		1				1							
21	16										1										
22	23					2		1	2	2					1						
23	16		1	1	1																
24	9	1																			
25	17		1			1															
26	23	2	1			1	3				1			1	1					1	
27	19			1		2		2		1											
28	16	1			1	2	2														
29	18		1		1						1										1
30	13			1	1			2						1				1			1
31	29	2					1								1			1		1	
Sept. 1	23			2	1	1												1	1		
2	27	1		1	2		1				2		1			2	1				
3	17				1	1	2														
4	9	2			1				1						1	1					
5	3	1													1						
6	14	1				3					1	1				1		2			
7	8										1				1						
8	3									1					1						
11	1																			1	
Larvæ..	331	11	4	6	9	14	10	6	3	5	7	1	1	3	7	4	1	5	1	3	2

	Days.
Average length of feeding period	37.55
Maximum length of feeding period	68
Minimum length of feeding period	20

CODLING MOTH BAND STUDIES OF 1916.

The same orchards, the Edwards and Hamilton, that were used in the band studies in 1915 were again made use of in 1916. As in 1915, the larvæ were collected every three days from beneath burlap bands that encircled the trunks of certain trees and were kept under conditions identical with those that obtained the previous season.

The data from the studies of the larvæ collected in the Edwards orchard are given in Table LVI, in which it will be found that 50

FIG. 31.—Number of codling moth larvæ collected from banded trees, Edwards orchard, Grand Junction, Colo., 1916.

collections were made beginning June 17 and ending November 11. During this period 4,998 larvæ were collected. Figure 31 represents the rate at which the larvæ were leaving the fruit during the three-day intervals throughout the season. It will be noted in the table that 49.19 per cent of the larvæ transformed to the adult stage in 1916, and that the remainder, 50.81 per cent, were wintering individuals. None of the larvæ collected in this orchard after August 19 transformed until the spring of the following year. The percentage of moths emerging in 1916 from each collection is shown diagrammatically in figure 32.

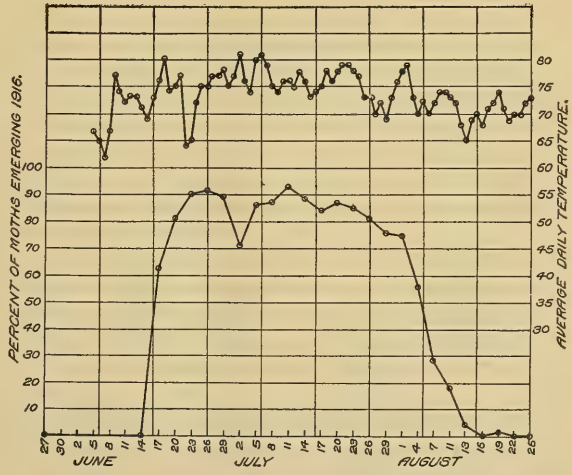


FIG. 32.—Percentage of codling moths emerging from band-collected material, Edwards orchard, Grand Junction, Colo., 1916.

TABLE LVI.—*Band-record experiment.—Codling moth larvæ collected at the Edwards orchard, Grand Junction, Colo., 1916.*

Date of collection, 1916.	Collection No.	Number of larvæ collected	Total number of moths emerging, 1916.	Per cent of— Moths emerging, 1916.	Per cent of— Individuals wintering.	Date of collection, 1916.	Collection No.	Number of larvæ collected.	Total number of moths emerging, 1916.	Per cent of— Moths emerging, 1916.	Per cent of— Individuals wintering.
June 17	1	32	20	62.50	37.50	Sept. 3	27	84	0	0.00	100.00
20	2	59	48	81.35	18.65	6	28	82	0	0.00	100.00
23	3	71	64	90.14	9.86	9	29	69	0	0.00	100.00
26	4	76	69	90.78	9.22	12	30	40	0	0.00	100.00
29	5	86	69	89.23	19.77	15	31	64	0	0.00	100.00
July 2	6	98	70	71.42	25.58	18	32	62	0	0.00	100.00
5	7	182	157	86.26	13.47	21	33	80	0	0.00	100.00
8	8	233	202	86.69	13.31	24	34	80	0	0.00	100.00
11	9	245	228	93.06	6.94	27	35	68	0	0.00	100.00
14	10	280	246	87.85	12.15	30	36	56	0	0.00	100.00
17	11	261	219	83.90	16.10	Oct. 3	37	58	0	0.00	100.00
20	12	198	172	86.86	13.14	6	38	24	0	0.00	100.00
23	13	226	192	84.95	15.05	9	39	24	0	0.00	100.00
26	14	215	175	81.39	18.61	12	40	18	0	0.00	100.00
29	15	192	146	76.04	23.96	15	41	13	0	0.00	100.00
Aug. 1	16	225	169	75.11	24.89	18	42	23	0	0.00	100.00
4	17	216	121	56.01	43.99	21	43	8	0	0.00	100.00
7	18	190	54	28.42	71.58	24	44	18	0	0.00	100.00
10	19	165	30	18.18	81.82	27	45	2	0	0.00	100.00
13	20	171	6	3.50	96.50	30	46	10	0	0.00	100.00
16	21	117	0	0.00	100.00	Nov. 2	47	9	0	0.00	100.00
19	22	142	2	1.40	98.60	5	48	6	0	0.00	100.00
22	23	149	0	0.00	100.00	8	49	4	0	0.00	100.00
25	24	111	0	0.00	100.00	11	50	2	0	0.00	100.00
28	25	83	0	0.00	100.00						
31	26	71	0	0.00	100.00		Total..	4,998	2,459	49.19	50.81

In the Hamilton orchard 46 collections of larvæ were made, beginning on June 17 and ending October 30, following the harvest of the fruit. A total of 5,716 larvæ was collected as will be seen by reference to Table LVII. Of this number 33.60 per cent transformed to the imago in 1916 and 66.40 per cent wintered. The percentage of transforming larvæ from each collection in 1916 is shown in the graph, figure 33. No larvæ transformed in 1916 from any collection made in this orchard after August 22. Figure 34 represents the number of larvæ collected from banded trees at each interval.

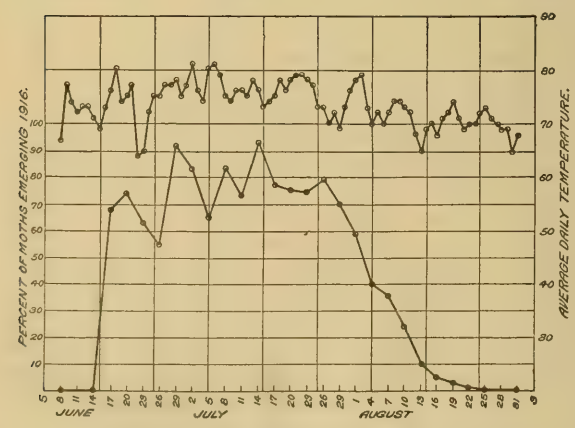


FIG. 33.—Percentage of codling moths emerging from band-collected material, Hamilton orchard, Grand Junction, Colo., 1916.

In figure 35 the graph is intended to show the average daily temperatures and the number of first and second brood moths that

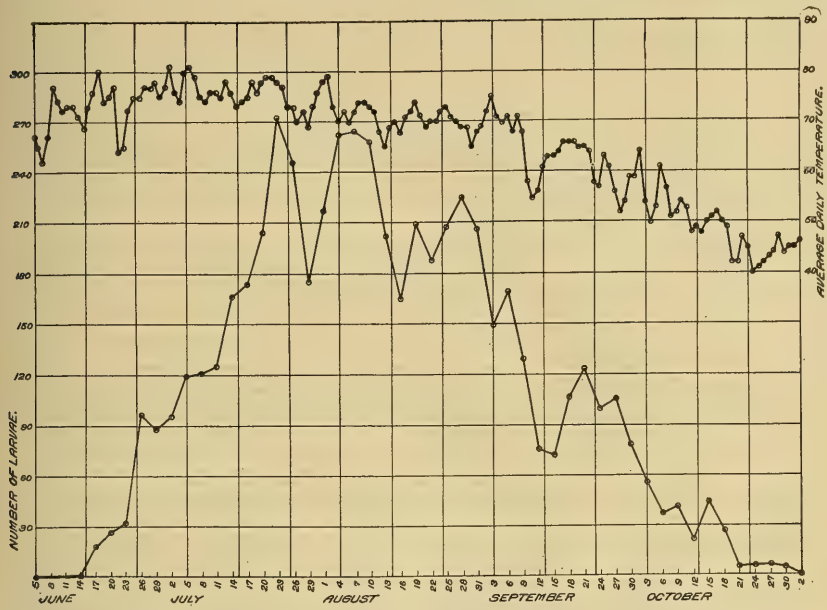


FIG. 34.—Number of codling moth larvæ collected from banded trees, Hamilton orchard, Grand Junction, Colo., 1916.

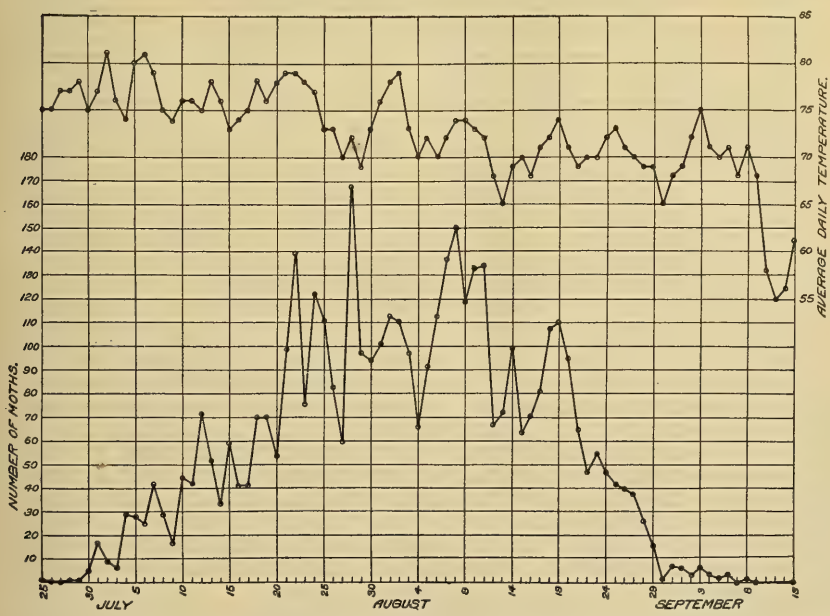


FIG. 35.—Time of emergence of codling moths from band-collected material, Hamilton and Edwards orchards, Grand Junction, Colo., 1916.

emerged from the larvæ collected from the banded trees at both the Edwards and Hamilton orchards. The first moth emerged June 25, the last September 8, a period of about two and a half months. The highest number of moths that issued in one day from this combined material was 167 on July 28, and this day was almost midway between the date of the first and last emergence. It will be recalled that, according to the insectary bred material, there was an overlapping of the first and second brood moths from August 7 to August 19 and that August 13 was theoretically considered as the dividing line between the two broods.

TABLE LVII.—*Band-record experiment, codling moth larvæ collected at the Hamilton orchard, Grand Junction, Colo., 1916.*

Date of collection, 1916.	Collection No.	Number of larvæ collected	Total number of moths emerging, 1916.	Per cent of—		Date of collection, 1916.	Collection No.	Number of larvæ collected.	Total number of moths emerging, 1916.	Per cent of—	
				Moths emerging, 1916.	Individuals wintering.					Moths emerging, 1916.	Individuals wintering.
June 17	1	19	13	68.42	31.58	Aug. 28	25	225	0	0.00	100.00
20	2	27	20	74.07	25.93	31	26	206	0	0.00	100.00
23	3	32	20	62.50	37.50	Sept. 3	27	149	0	0.00	100.00
26	4	96	53	55.20	44.80	6	28	169	0	0.00	100.00
29	5	88	81	92.04	7.96	9	29	129	0	0.00	100.00
July 2	6	95	79	83.15	16.85	12	30	76	0	0.00	100.00
5	7	119	77	64.70	35.30	15	31	72	0	0.00	100.00
8	8	121	100	82.64	17.36	18	32	106	0	0.00	100.00
11	9	125	91	72.80	27.20	21	33	123	0	0.00	100.00
14	10	165	154	93.33	6.67	24	34	99	0	0.00	100.00
17	11	173	134	77.45	22.55	27	35	105	0	0.00	100.00
20	12	204	153	75.00	25.00	30	36	78	0	0.00	100.00
23	13	272	201	73.89	26.11	Oct. 3	37	56	0	0.00	100.00
26	14	246	194	78.86	21.14	6	38	37	0	0.00	100.00
29	15	175	122	69.71	30.29	9	39	41	0	0.00	100.00
Aug. 1	16	217	128	58.98	41.02	12	40	22	0	0.00	100.00
4	17	262	106	40.45	59.55	15	41	44	0	0.00	100.00
7	18	264	94	35.60	64.40	18	42	27	0	0.00	100.00
10	19	258	63	24.41	75.59	21	43	6	0	0.00	100.00
13	20	202	21	10.39	89.61	24	44	6	0	0.00	100.00
16	21	164	8	4.87	95.13	27	45	7	0	0.00	100.00
19	22	209	6	2.87	97.13	30	46	5	0	0.00	100.00
22	23	[1] 188	1	[2] 0.54	[2] 99.46						
25	24	207	0	0.00	100.00		Total..	5,716	1,919	[2] 33.60	[2] 66.40

[1] 5 larvæ killed in handling. [2] All percentages based upon number of live larvæ collected.

NATURAL ENEMIES OF THE CODLING MOTH.

PREDACIOUS ENEMIES.

The codling moth in the Grand Valley is seldom attacked by predacious insects and, as a result, the reduction of the pest by this means is quite inconsequential. A small beetle, *Tenebroides corticalis* Melsh., which, in its larval and adult stages, is known to feed upon the codling moth larva, was occasionally taken from beneath the bands on apple trees. A spider, *Coriarachne versicolor* Keys., was found from time to time feeding upon larvæ of the codling moth. This spider is a general feeder and is commonly found beneath the loose bark of orchard and shade trees.

In view of the comparative absence of predacious insect enemies an attempt was made to introduce the well-known beetle *Calosoma*

sycophanta L., which has been instrumental in partially reducing the number of brown-tail moth and gipsy moth larvæ as well as other lepidopterous larvæ of the New England States. Over 1,000 of these beetles were released in June, 1915, but none were recovered after their distribution.

PARASITIC ENEMIES.

The parasitic enemies of the codling moth in the Grand Valley play a very unimportant rôle in its control, although in one instance an egg parasite, *Trichogramma minutum* Riley, was found quite abundant in the field in a small pear orchard. Some of the foliage surrounding the fruit was pulled at random and then was examined for eggs. Out of the first 100 eggs found, 15 were parasitized by this insect. As many as three of these parasites were found developing within one codling moth egg, while quite frequently two of the parasites inhabited the same egg.

Another parasite, *Dibrachys clisiocampae* Fitch, was found to attack the codling-moth larva and continue to feed upon the host after it had transformed to the pupa stage.

The parasite *Arthrolytus apatelae* Ashmead was also reared from material collected in the field.

In general, the occurrence of parasitism was so infrequent that little good was accomplished by this class of natural enemies.

MISCELLANEOUS STUDIES.

EFFECT OF COOL TEMPERATURES ON EMERGENCE OF MOTHS OF THE SPRING BROOD.

In laboratory cellar.—As a means of studying the influence of cool temperatures upon the emergence of moths of the spring brood, a number of wintering larvæ were placed in the cellar of the laboratory. This cellar was of the usual type, having stone walls and a cement floor, and was moderately dry. The temperature and atmospheric conditions within would compare somewhat with the fruit cellars or caves in which fruit is sometimes stored in the Grand Valley. The cage containing the insects was examined daily and the results of the observations will be found in Table LVIII.

A study of this table will show that the first moth, under cellar conditions, did not emerge until May 30, or 18 days after the first adult appeared in the outdoor insectary. It is noteworthy that the last emergence of moths in the cellar cage and the insectary cages occurred the same day, June 29. From these observations it would appear that the lower temperature in the cellar had a retarding influence in the development of the insect for some time, but that after the insects had been subjected to a sufficient accumulation of effective temperatures, their complete transformations to the adult stage were not long delayed.

TABLE LVIII.—*Emergence of codling moths of the spring brood, laboratory cellar, Grand Junction, Colo., 1915.*

Date of observation and collection.	Number of moths.	Date of observation and collection.	Number of moths.	Date of observation and collection.	Number of moths.	Date of observation and collection.	Number of moths.	Date of observation and collection.	Number of moths.
May 30	1	June 10	3	June 15	6	June 20	9	June 27	2
31	2	11	6	16	15	21	2	28	3
June 6	4	12	3	17	7	22	2	29	2
7	1	13	1	18	13	23	1		
8	3	14	2	19	8	26	4	Total	105
9	5								

In fruit cellar.—Observations were also taken of the time of emergence of moths of the spring brood in a fruit cellar beneath a large packing house where considerable wormy fruit had been temporarily stored the previous fall. The records are from moths secured from a cage containing wintering larvæ and also from moths captured at a screened window. The observations were made only on the dates recorded in Table LIX. In this table it will be seen that 105 moths emerged in the cage, while 48 were captured at the window. In the latter connection it should be borne in mind that the records of the insects found at the window do not necessarily indicate the true time of their emergence. The emergence period of the caged insects in the fruit cellar was somewhat similar to that in the laboratory cellar.

It will be observed from the foregoing that moths may be expected to emerge from fruit cellars later than those out-of-doors, and this emergence augments, to a certain extent, the late injury as caused by the first brood of larvæ.

TABLE LIX.—*Emergence of codling moths of the spring brood, cellar of fruit packing house, Grand Junction, Colo., 1915.*

Date of observation and collection.	Number of moths—		Date of observation and collection.	Number of moths—		Date of observation and collection.	Number of moths—	
	In cage.	Found at screened window.		In cage.	Found at screened window.		In cage.	Found at screened window.
June 2	1	0	June 19	5	2	July 3	0	2
8	21	0	21	6	16	7	1	8
12	32	0	23	3	3	26	0	1
15	26	0	24	1	4			
16	7	1	29	2	11	Total	105	48

TIME OF DAY MOTHS EMERGE.

During the seasons of 1915 and 1916 observations were made to obtain data relative to the time of day the moths of the spring and first broods emerged in largest numbers. These studies are reported herewith.

Moths of the spring brood, 1915.—A certain lot of wintering larvæ were placed in cages with the view to determining at what periods of the day the moths of the spring brood emerge. The observations were taken at 8 a. m., noon, and 6 p. m. from May 14 to May 28, inclusive. It will be noted in Table LX that 1,189 moths issued during the 15-day period; 60, or 5.05 per cent, issued between 6 p. m. and 8 a. m.; 928, or 78.05 per cent, between 8 a. m. and 12 o'clock noon, and 201 moths, or 16.90 per cent, between 12 noon and 6 p. m.

TABLE LX.—*Emergence of codling moths of the spring brood, Grand Junction, Colo., 1915.*

Date of observation.	Number of moths emerging—			Date of observation.	Number of moths emerging—		
	6 p. m. to 8 a. m.	8 a. m. to 12 noon.	12 noon to 6 p. m.		6 p. m to 8 a. m.	8 a. m. to 12 noon.	12 noon to 6 p. m.
May 14	0	0	19	May 23	0	104	20
15	9	23	13	24	5	175	17
16	0	114	12	25	9	109	0
17	34	98	16	26	0	25	22
18	0	21	8	27	0	75	29
19	1	28	0	28	1	75	24
20	1	0	0				
21	0	3	5	Total..	60	928	201
22	0	78	16	Per ct..	5.05	78.05	16.90

Moths of the first brood, 1915.—Records of the emergence of moths of the first brood were taken hourly from 6 a. m. to 6 p. m., inclusive, and again at 9 p. m. and 12 o'clock midnight from August 16 to 20, inclusive. A total of 641 moths was used in this study, the details of which are given in Table LXI, in which it will be observed that no moths issued between midnight and 6 a. m., nor did any emerge between 6 a. m. and 7 a. m. During the 5-hour interval from 9 a. m. to 2 p. m., 431 moths, or 67.24 per cent, issued. The maximum emergence for any one hour occurred during the period from 9 a. m. to 10 a. m. From 6 p. m. to 7 a. m., a period of 13 hours, there emerged 35 moths, or 5.46 per cent of the total.

TABLE LXI.—*Emergence of codling moths of the first brood, hourly, from 6 a. m. to 6 p. m., and at 9 p. m. and 12 midnight, Grand Junction, Colo., 1915.*

Date of emergence of moths.	Observation No.	Number of moths emerging at—															Total number of moths.
		A. M.							P. M.								
		6	7	8	9	10	11	12	1	2	3	4	5	6	9	12	
Aug. 16	1	....	....	....	....	3	14	2	6	4	7	5	3	1	5	....	50
17	2	....	....	....	....	48	36	18	3	8	2	7	12	8	10	....	152
18	3	....	....	....	16	24	25	11	12	11	10	14	12	1	6	1	143
19	4	....	....	1	9	34	22	20	25	12	8	8	10	9	3	....	161
20	5	....	....	1	1	25	21	16	18	13	13	8	6	3	8	2	135
Total.	.....	0	0	2	26	134	118	67	64	48	40	42	43	22	32	3	641

Moths of the spring brood, 1916.—Observations of the time of emergence of moths of the spring brood were made hourly from 7 a. m. to 6 p. m. from May 17 to 31, inclusive, as recorded in Table LXII. It will be noted therein that the largest number of moths issued between 12 o'clock noon and 1 p. m. The heaviest emergence period was the five-hour interval from 9 a. m. to 2 p. m., during which 895 moths, or 67.14 per cent of the total number of 1,333 moths, issued. Only 40 moths, or 3 per cent of the total, emerged during the period of 13 hours from 6 p. m. until 7 a. m.

TABLE LXII.—*Emergence of codling moths of the spring brood, hourly, from 7 a. m. to 6 p. m., Grand Junction, Colo., 1916.*

Date of emergence of moths.	Observation No.	Number of moths emerging at—												Total number of moths.
		A. M.						P. M.						
		7	8	9	10	11	12	1	2	3	4	5	6	
May 17	1	----	----	----	----	----	10	34	5	2	2	----	----	53
18	2	1	----	----	1	30	19	9	4	6	----	----	----	70
19	3	----	4	4	27	27	27	15	18	5	3	----	1	131
20	4	----	----	----	----	----	----	----	----	----	----	----	----	0
21	5	----	----	----	----	----	----	----	----	----	7	2	2	11
22	6	----	1	----	7	21	40	49	19	12	2	5	1	157
23	7	----	----	----	----	29	50	32	17	14	5	2	----	149
24	8	[1]37	29	55	34	25	8	13	15	6	10	7	6	245
25	9	1	1	----	----	----	----	17	25	15	1	1	1	62
26	10	----	----	----	----	----	----	15	20	3	2	----	----	40
27	11	----	----	----	----	----	3	24	11	8	3	1	----	50
28	12	----	----	----	----	50	24	18	7	6	3	1	----	109
29	13	----	----	----	2	21	15	19	19	10	5	----	----	91
30	14	1	----	2	40	23	14	13	5	3	4	5	----	110
31	15	----	----	----	12	12	8	8	8	2	1	3	1	55
Total	----	40	35	61	123	238	218	266	173	92	48	27	12	1,333

[1] About 5 of these moths found at 7 a. m. were spreading their wings, having emerged between 6 and 7 a. m.

Moths of the first brood, 1916.—A study of the time of emergence of first-brood moths was begun July 17 and ended August 4, and during this time observations were taken hourly from 6 a. m. to 6 p. m. The record of the observations shows that a total of 1,761 moths emerged, as is given in Table LXIII. The maximum emergence for a 1-hour period was 213 moths, which issued from 9 to 10 a. m. During the 5-hour period from 9 a. m. to 2 p. m. 923 issued, or 52.41 per cent of the total number of moths emerging. For the 13-hour period from 6 p. m. to 7 a. m. 61 moths, or 3.46 per cent. emerged.

From the foregoing studies it will be noted that the majority of the moths of the spring and first broods emerged during the latter part of the morning and early part of the afternoon, with the maximum emergence usually occurring from 9 to 11 a. m. During the 5-hour period from 9 a. m. to 2 p. m. from 52 to 67 per cent of the moths emerged; whereas during the 13-hour interval from 6 p. m. to 7 a. m. only from 3 to 5 per cent issued.

TABLE LXIII.—*Emergence of codling moths of the first brood, hourly, from 6 a. m. to 6 p. m., Grand Junction, Colo., 1916.*

Date of emergence of moths.	Observation No.	Number of moths emerging at—													Total number of moths.
		A. M.							P. M.						
		6	7	8	9	10	11	12	1	2	3	4	5	6	
July 17	1	....	....	....	3	6	6	5	1	5	2	4	6	3	41
18	2	....	....	1	....	11	13	11	7	9	6	3	5	3	69
19	3	1	....	1	4	7	9	12	4	8	4	11	7	3	71
20	4	....	2	1	1	1	5	2	7	8	1	12	5	8	53
21	5	1	3	1	9	13	9	8	11	12	13	10	5	1	96
22	6	4	....	....	8	20	32	21	12	9	16	10	5	4	141
23	7	2	2	2	8	25	15	5	5	4	1	2	2	3	76
24	8	....	....	....	1	....	5	12	16	10	22	15	32	6	119
25	9	3	1	....	4	10	18	16	6	....	9	11	25	8	111
26	10	3	1	....	2	3	4	1	5	6	4	18	21	9	77
27	11	9	1	5	8	6	4	2	4	11	12	6	....	....	68
28	12	1	....	....	19	26	6	4	9	16	35	30	18	3	167
29	13	1	1	....	2	5	7	8	16	15	8	13	11	7	94
30	14	4	2	....	4	26	20	1	3	4	3	7	10	7	91
31	15	7	....	....	8	12	4	2	20	16	13	10	5	6	103
Aug. 1	16	5	....	1	12	20	16	15	18	10	1	6	11	2	117
2	17	1	3	....	10	11	27	25	9	7	8	5	4	....	110
3	18	1	1	3	7	4	5	9	22	13	8	13	9	2	97
4	19	1	....	....	4	7	1	2	3	2	11	3	9	17	60
Total	.....	44	17	15	114	213	206	161	178	165	177	189	190	92	1,761

CODLING-MOTH FLIGHT TRIALS.

In connection with the habits of the codling moth, the question, "How far does the codling moth fly?" has frequently been asked, but it has not been possible to answer this query definitely on account of the lack of satisfactory data. It is generally conceded by the fruit growers of the Grand Valley that the codling moth migrates to a certain extent. They have observed that the outside rows of their orchards frequently have a greater percentage of wormy fruit, which they attribute to the immigration of moths from near-by orchards. It has also been found that the fruit on trees in the vicinity of the packing houses is, as a rule, quite wormy, due to the migration of the moths from the packing houses.

According to the observations of the writers, it is believed that the codling moth does not migrate long distances in a continuous flight, but by means of short flights may proceed from one tree to the next or fly across a road from one orchard to the adjoining or from the packing house to the neighboring trees, or occasionally fly a few hundred feet from one orchard to another. The normal flight, however, is restricted, as my be noted about dusk, when the moths are most active and may be seen flitting about in a tree or flying from one tree to another near by.

Perhaps the strongest evidence that the moths do not migrate in large numbers to any considerable extent was noted in 1915, when only a few smudged orchards, outside of the Palisade district, had a fruit crop. While the apples in these protected orchards were quite

wormy, it is believed that had there been a large influx of moths from the hundreds of acres of surrounding orchards in which there was no fruit, it would have been practically impossible to have saved the crop with the normal spraying schedule.

In order to determine how far the adults can actually fly, it was thought desirable to make some moth-flight tests. Accordingly, trials were made on the mornings of June 11, 17, 24, July 27, 29, and August 3, 1915. These tests were usually made early in the morning and, in so far as possible, when the atmosphere was quiet and the temperature moderately low in order that the moths would fly at a slow speed. When the wind is moderate to strong or the temperature high, the moths are very rapid in their flight, so that it is impossible to follow them.

The moths were released one at a time from a central point, and Mr. Van Leeuwen and the senior author followed their course on foot. In all, several hundred moths were released and out of this number it was possible to secure data on a few. In many instances the moths ascended high into the air and were lost from view, in other instances they dropped into bushes, while in some cases their flight was either too erratic or swift to follow. The flight of the male moths was generally much more irregular and speedy than that of the other sex.

In determining the distance covered, measurements were made from the starting point to the place where the moths dropped or were lost from view. It should be noted, however, that the actual distance between the starting and finishing points, as measured by pacing, was usually only a small part of the distance the moths flew, since they seldom went in a straight line and it was impossible to take into account the numerous deviations from a direct course. Nevertheless, an attempt was made to estimate the number of feet actually traveled during the flight whenever the moths proceeded in a new direction for a considerable distance. This was done by counting the steps of the observers and allowing a certain distance per step. In this connection it should be borne in mind that the estimated distances, although approximate, are conservative.

In Table LXIV the flight records of 35 moths are given. Three of these covered a distance of over a thousand feet in one flight, measuring from the point of release to the place where the moths disappeared from view or dropped to the ground. The maximum air-line distance of 1,344 feet was made by a male moth. One female moth that flew, in 6½ minutes, a distance of 1,035 feet measured in a straight line, traveled an estimated distance of 3,000 feet and was still flying when it disappeared from sight. Another female moth, after flying continuously for 7½ minutes, was lost from view.

It would seem from the foregoing that the codling moth is capable of making a fairly long and sustained flight, but it does not neces-

sarily follow from this that the moth naturally migrates to any considerable extent.

TABLE LXIV.—*Flight records of the codling moth, Grand Junction, Colo., 1915.*

Moth No.	Sex of moth.	Date of flight.	Actual distance between starting and finishing points.	Estimated distance of flight between starting and finishing points.	Remarks.
			Feet.	*Feet.*	
1	.....	June 11	105	.....	In two flights.
2	Male....	...do....	120	.....	Lost from view.
3	...do....	...do....	360	720	Dropped to ground; when released, flew from sight.
4	...do....	...do....	138	.....	On wing 2 minutes, then lost from view.
5	Female .	...do....	189	.....	Do.
6	...do....	...do....	840	2,500	On wing 5 minutes, then lost from view.
7	...do....	...do....	600	1,800	On wing 7½ minutes, then lost from view.
8	...do....	...do....	420	1,200	In two flights, on wing 6½ minutes, then lost from view.
9	...do....	...do....	180	.....	Flew out of sight.
10	.....	June 17	390	600	On wing 3 minutes, then lost from view.
11	.....	...do....	579	750	On wing 4 minutes, then lost from view.
12	Male....	...do....	249	.....	On wing 1 minute, then lost from view.
13	Female .	June 24	715	.....	On wing 1½ minutes, then lost from view; swift flier.
14	...do....	...do....	294	.....	On wing 1¼ minutes, then lost from view.
15	...do....	...do....	135	.....	Dropped to bushes.
16	...do....	...do....	276	.....	On wing 1½ minutes, dropped to bushes.
17	...do....	...do....	180	350	On wing 2 minutes, then lost from view.
18	...do....	...do....	717	1,000	On wing 2½ minutes, then lost from view.
19	Male....	...do....	507	.....	Very erratic; exhausted after 6-minute flight.
20	...do....	July 27	102	.....	Dropped to bushes.
21	.....	...do....	699	749	On wing 2 minutes.
22	Female .	...do....	1,035	3,000	On wing 6½ minutes, then lost from view
23	...do....	...do....	910	.....	Lost from view.
24	...do....	...do....	595	.....	On wing 2 minutes.
25	Male....	...do....	336	.....	On wing 1 minute.
26	...do....	...do....	150	.....	
27	Female .	...do....	1,155	.....	On wing 4 minutes, then lost from view
28	Male....	...do....	1,344	.....	
29	Female .	July 29	117	.....	
30	Male....	...do....	590	.....	
31	Female .	...do....	792	.....	
32	.....	...do....	1,356	.....	In two flights.
33	Female .	Aug. 3	747	.....	Dropped to ground, apparently exhausted
34	Male....	...do....	789	.....	In two flights, on wing 2 minutes.
35	Female .	...do....	423	.....	In three flights, on wing 1¾ minutes.

TIME OF COPULATION.

Observations of the time of copulation of the codling moth were taken during the seasons of 1915 and 1916. (See Pl. I, B.) The data for 1916 are more extensive than those for the preceding year. No attempt was made to watch the moths closely at all times, but instead they were examined at intervals to note if they had separated.

In 1915 the following records were secured:

Moths of the spring brood.—May 30, one pair found in copula at 7 p. m.; June 8, one at 6.50 a. m.; June 9, one at 6.45 a. m., and another pair at 7 a. m.

Moths of the first brood.—The data for moths of this brood are presented in Table LXV.

The observations in 1916 of the copulatory period of moths are given in two tables: Table LXVI for moths of the spring brood and Table LXVII for moths of the first brood.

TABLE LXV.—*Observations of the copulatory period of codling moths of the first brood, Grand Junction, Colo., 1915.*

Pair No.	Date found in copula.	Time found in copula.	Moths separated.	Minimum time attached.	
				Hours.	Minutes.
1	Aug. 7	8.00 a. m.	After 10 a. m.	2	
2	...do...	8.45 a. m.	After 2.30 p. m.	5	45
3	Aug. 10	6.30 a. m.	After 9 a. m.	2	30
4	Aug. 14	8.40 a. m.	After 3 p. m.	6	20
5	Aug. 16	7.00 a. m.	Before 3 p. m.		
6	...do...	9.30 p. m.	After 12.45 a. m. (Aug. 17)	3	15
7	...do...	9.50 p. m.	After 12 midnight	2	10
8	...do...	9.55 p. m.	Before 12 midnight		
9	Aug. 18	9.05 a. m.	Before 1.30 p. m.		
10	Aug. 19	2.45 a. m.	Before 6 a. m.		
11	...do...	...do...	After 7.15 a. m.	4	30
12	...do...	9.15 p. m.	Before 12 midnight		

TABLE LXVI.—*Observations of the copulatory period of codling moths of the spring brood, Grand Junction, Colo., 1916.*

Pair No.	Date moths emerged.	Date found in copula.	Time found in copula.	Moths separated subsequent to—	Minimum time attached.	
					Hours.	Minutes.
			A. M.			
1		May 19	9.40	6.30 p. m.	8	50
2	May 16	May 25	10.30	6.06 p. m., May 26	31	36
3	May 19	May 30	10.50	1 p. m.	2	10
4	...do...	May 31	8.59	11.02 a. m.	2	3
5	May 22	...do...	7.59	3 p. m.	7	1
6	May 23	May 25	11.50	12 noon, May 27	48	10
7	...do...	May 30	10.23	10.55 a. m.		32
8	...do...	May 31	7.45	9.37 a. m.	1	52
9	...do...	June 2	7.58	1.40 p. m.	5	42
10	...do...	June 3	7.12	2.15 p. m.	7	3
11	...do...	...do...	7.12	6.25 p. m.	11	13
12	...do...	...do...	7.14	6.25 p. m.	11	11
13	May 24	May 31	7.29	8.06 a. m.		37
14	...do...	June 2	7.00	1.40 p. m.	6	40
15	...do...	...do...	7.15	5.48 p. m.	10	33
16	...do...	June 13	7.45	1.48 p. m.	6	3
17	May 27	June 4	6.45	3.07 p. m.	8	22
18	...do...	June 5	6.45	11.15 a. m.	4	30
19	May 28	June 2	6.45	7 a. m.		15
20	May 29	...do...	6.25	5.48 p. m.	11	23
21	May 31	June 3	6.25	9.50 a. m.	3	25
22	June 3	June 20	7.25	1.30 p. m.	6	5
23	June 4	June 7	6.25	11 a. m.	4	35
24	...do...	June 9	6.35	2.30 p. m.	7	55
25	June 8	June 12	6.20	6.15 p. m.	11	55
26	June 11	June 13	6.15	6.15 p. m.	12	
27	June 15	June 21	6.45	3 p. m.	8	15
28	June 16	June 23	6.50	5.45 p. m.	10	55

TABLE LXVII.—*Observations of the copulatory period of codling moths of the first brood, Grand Junction, Colo., 1916.*

Pair No.	Date moths emerged.	Date found in copula.	Time found in copula.	Moths separated subsequent to—	Minimum time attached.	
					Hours.	Minutes.
			A. M.			
1	July 24	July 25	7.43	11.40 a. m.	3	57
2	July 27	Aug. 2	7.20	4.50 p. m.	9	30
3	July 28	July 31	7.13	12.15 p. m.	5	2
4	...do...	...do...	7.19	12.15 p. m.	4	56
5	Aug. 3	Aug. 5	6.54	2.37 p. m.	7	43
6	...do...	...do...	9.52	6.00 p. m.	8	8
7	Aug. 4	Aug. 11	7.29	5.48 p. m.	10	19
8	Aug. 5	Aug. 7	7.00	4.55 p. m.	9	55
8	...do...	Aug. 8	7.05	12.19 p. m.	5	14
9	Aug. 6	Aug. 13	6.20	10.09 a. m.	3	49
10	...do...	Aug. 20	7.45	10.00 p. m.	14	15
11	Aug. 9	Aug. 12	7.06	2.45 p. m.	7	39
12	Aug. 10	Aug. 15	7.25	12.10 p. m.	4	45
13	Aug. 11	Aug. 13	6.00	10.40 a. m.	4	40
14	Aug. 12	Aug. 23	7.45	8.02 a. m.	.....	17
15	Aug. 14	Aug. 17	7.20	11.27 a. m.	4	7
16	...do...	Aug. 20	6.50	3.55 p. m.	9	5
17	...do...	Sept. 1	7.40	Died previous to separation.		
18	Aug. 28	...do...	7.00	8.05 a. m.	1	5

TIME OF DAY MOTHS OVIPOSIT.

A series of studies was inaugurated in 1915 and continued in 1916 to ascertain the time of day the moths deposit their eggs most freely. The results of these studies are given herewith.

Moths of the first brood, 1915.—This experiment included 11 cages in which were confined a number of male and female moths. The observations were made at 3 p. m., 6 p. m., 9 p. m., 12 o'clock midnight, 6 a. m., 9 a. m. and 12 o'clock noon, or, in other words, daily every 3 hours except at 3 a. m. These studies were commenced at 12 o'clock noon August 16 and were concluded at 6 a. m. August 21. At each examination the old foliage was removed and a fresh supply furnished, and at the same time the number of eggs deposited on the sides of the cages was recorded and the eggs removed. Some eggs were deposited on the sand in the bottom of the jars, but as these could not be accurately counted, they were not taken into consideration.

In Table LXVIII the tabulated data of the time of deposition of 3,621 eggs will be found in addition to the mean temperatures during the periods of observation. This table has been summarized and the data presented in Table LXIX, by reference to which it will be noted that the great majority of the eggs were deposited between 12 o'clock noon and 9 p. m. The time of greatest deposition occurred just before dusk, the moths being very active at this time. It is of interest to note that with a mean temperature of 78.90° F. during 5 observation periods from 9 a. m. till 12 o'clock noon, only 2.34 per cent of the eggs were laid, whereas the moths laid much more abundantly with both higher and lower mean temperatures when these occurred later in the day.

TABLE LXVIII.—*Time of oviposition by codling moths of the first brood; observations taken daily every three hours, except at 3 a. m., Grand Junction, Colo., 1915.*

Cage No.—		1		2		3		4		5		6		7		8		9		10		11		Number of eggs deposited on—		Total number of eggs deposited.	Mean temperature between observations.
Moths emerged August—		10		10		10		11		11		12		12		12		13		13		13					
		Number of eggs deposited on—																									
Date of observation.	Time of observation.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.		° F.
Aug. 16	12 m.	8	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	13	77.25
	3 p. m.	28	22	5	19	25	3	24	5	63	18	7	10	125	29	0	5	30	24	0	10	9	68	316	213	529	79.00
	6 p. m.	64	87	18	11	24	41	0	2	33	10	1	1	18	15	2	1	17	32	8	87	25	13	210	300	510	75.25
	9 p. m.	6	8	3	1	0	3	0	0	4	1	0	1	0	0	38	1	0	0	0	3	12	0	63	18	81	67.50
	12 mt.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2	60.25
17	6 a. m.	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	3	3	55.00
	9 a. m.	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	4	4	66.50
	12 m.	0	2	0	2	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	10	10	77.25
	3 p. m.	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	15	15	17	18	35	87.25
	6 p. m.	4	17	1	1	22	37	38	10	5	0	7	2	36	12	2	0	0	1	3	1	8	3	126	84	210	87.00
	9 p. m.	38	20	15	0	15	46	16	11	131	2	10	1	31	11	32	2	2	2	45	32	28	14	363	141	504	74.25
	12 mt.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	3	0	5	5	63.00
18	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59.43
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	4	0	4	64.25
	12 m.	0	2	2	1	1	1	0	1	0	0	0	0	2	6	1	0	0	5	0	0	4	0	10	16	26	80.75
	3 p. m.	3	9	0	0	3	3	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	7	14	21	90.00
	6 p. m.	11	21	16	1	16	35	30	4	23	28	3	0	0	0	14	0	51	2	1	3	18	1	183	95	278	85.50
	9 p. m.	28	25	9	3	5	33	13	0	36	21	7	1	31	0	19	0	2	0	41	21	30	1	221	105	326	74.25
	12 mt.	0	0	0	0	0	3	0	1	0	1	0	3	0	0	0	0	0	2	0	0	0	1	0	11	11	63.50
19	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57.43
	9 a. m.	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	1	0	0	0	9	9	63.75
	12 m.	4	4	0	2	2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	8	6	14	79.00
	3 p. m.	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	7	0	0	0	8	2	10	89.00
	6 p. m.	3	2	5	1	12	13	21	0	7	2	67	8	4	1	53	0	7	0	4	0	0	0	183	27	210	88.00
	9 p. m.	14	10	14	1	6	26	20	0	32	9	65	13	15	3	56	6	4	4	2	11	26	3	254	86	340	75.25
	12 mt.	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	1	5	6	66.75
20	6 a. m.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	59.86
	9 a. m.	0	0	0	0	0	4	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1	6	7	63.75
	12 m.	0	1	0	0	1	0	4	0	0	3	0	0	0	2	1	0	0	0	0	0	8	2	14	8	22	80.25
	3 p. m.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	3	90.50
	6 p. m.	2	7	1	1	2	10	9	4	4	0	12	6	2	0	9	0	11	1	67	10	9	0	128	39	167	89.75
	9 p. m.	6	8	12	0	17	11	25	0	15	11	10	1	19	2	12	2	1	2	60	17	10	0	187	54	241	77.25
	12 mt.	0	9	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	1	2	0	0	2	14	16	66.50
21	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	2	63.29
Total		221	263	101	45	151	274	206	39	358	110	189	48	288	86	239	18	127	82	241	206	205	124	2,326	1,295	3,621	.....

m=noon; mt.=midnight.

TABLE LXIX.—*Time of oviposition by codling moths of the first brood; observations taken daily every three hours, except at 3 a. m.; Grand Junction, Colo., 1915; summary of Table LXVIII.*

Number of observation periods.	Period of observation.	Total number of eggs deposited.	Average number of eggs per oviposition period.	Per cent of eggs deposited per oviposition period.	Mean temperature during oviposition periods.
					°*F.*
5	12 mt. to 6 a. m....	7	1.40	0.19	59.00
4	6 a. m. to 9 a. m...	24	6.00	.83	64.56
5	9 a. m. to 12 m.....	85	17.00	2.34	78.90
5	12 m. to 3 p. m....	598	119.60	16.49	87.15
5	3 p. m. to 6 p. m...	1,375	275.00	37.91	85.10
5	6 p. m. to 9 p. m...	1,492	298.40	41.14	73.70
5	9 p. m. to 12 mt....	40	8.00	1.10	64.00

m=noon; mt.=midnight.

Moths of the spring brood, 1916.—The study of the time of oviposition by moths of the spring brood was commenced at 12 o'clock noon on June 5 and the observations were made daily every 3 hours, except at 3 a. m., until 12 o'clock noon June 12, a period of one week. The details of this study are presented in Table LXX and summarized in Table LXXI. By reference to the latter it will be noted that over 79 per cent of the eggs were deposited from 3 p. m. to 9 p. m. It will be seen in the table that the mean temperature for the 7 days from 9 a. m to 12 o'clock noon was 76.39° F. Although this temperature is in no wise unfavorable for egg deposition, yet only 1.54 per cent of the eggs were deposited during this interval. Later in the day, with both higher and lower mean temperatures, much higher percentages of eggs were deposited. From 3 p. m. to 6 p. m. 58.80 per cent of the eggs were laid, the mean temperature being 82.92° F., or a little over 6° higher than the temperature from 9 a. m. to 12 o'clock noon. From 6 p. m. to 9 p. m., with a temperature of 73.14° F., 20.52 per cent of the eggs were deposited.

TABLE LXX.—*Time of oviposition by codling moths of the spring brood. Observations taken daily every three hours except at 3 a. m., Grand Junction, Colo., 1916.*

Cage No. —		1		2		3		4		5		6		7		8		9		10		Number of eggs deposited on—		Total number of eggs deposited.	Mean temperature between observations.
Moths emerged, May—		23		23		23		23		23		23		23		23		24		24					
Date of observation.	Time of observation.	Number of eggs deposited on—																							
		Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.		°F.
June 5	3 p. m.	0	0	0	0	16	0	0	0	0	0	2	0	3	0	0	0	0	0	1	4	22	4	26	81.25
	6 p. m.	15	0	18	0	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0	3	37	3	40	78.75
	9 p. m.	1	0	1	1	1	0	0	0	0	0	2	0	2	0	0	4	0	0	0	0	7	5	12	70.75
	12 mt.	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	65.00
June 6	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53.71
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56.75
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70.75
	3 p. m.	1	1	0	0	10	0	3	0	0	1	2	0	2	0	0	0	2	0	0	0	20	2	22	78.50
	6 p. m.	19	2	3	0	0	2	8	0	5	0	4	0	4	0	0	0	0	0	0	0	43	4	47	78.50
	9 p. m.	1	4	0	0	3	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4	11	15	68.50
	12 mt.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60.00
June 7	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49.14
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55.00
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	9	0	9	68.25
	3 p. m.	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	6	0	6	76.25
	6 p. m.	5	1	24	0	7	2	5	0	2	0	1	0	6	0	3	4	0	0	0	0	53	7	60	77.50
	9 p. m.	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	4	0	0	0	0	1	5	6	68.00
	12 mt.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56.00
June 8	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49.28
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57.50
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	71.50
	3 p. m.	4	2	0	1	15	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	23	3	26	84.00
	6 p. m.	2	1	2	0	15	0	36	0	34	0	0	0	1	0	0	0	0	1	0	0	90	2	92	85.25
	9 p. m.	4	2	19	0	0	1	6	2	0	0	0	0	0	0	0	0	0	0	0	0	29	5	34	76.75
	12 mt.	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	67.75
June 9	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66.28
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68.75
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81.50
	3 p. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91.75
	6 p. m.	0	0	0	0	2	0	28	0	18	0	1	0	0	0	0	0	37	1	0	0	86	1	87	90.75

	9 p. m...	2	7	1	0	9	1	3	0	2	0	0	0	0	0	0	0	0	0	0	0	17	8	25	80.50
	12 mt...	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	74.00
June 10	6 a. m...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62.57
	9 a. m...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67.25
	12 m....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81.75
	3 p. m...	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	88.25
	6 p. m...	0	0	0	0	5	5	0	0	15	0	1	0	0	0	0	0	0	0	2	0	23	5	28	85.75
	9 p. m...	1	14	0	0	3	5	2	0	2	0	0	0	5	0	0	0	0	0	1	0	14	19	33	73.00
	12 mt...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66.50
June 11	6 a. m...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60.42
	9 a. m...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65.25
	12 m....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79.25
	3 p. m...	0	0	0	0	0	0	3	0	0	0	0	0	1	0	2	0	1	0	0	0	7	0	7	86.25
	6 p. m...	0	6	0	0	0	0	2	0	11	0	0	0	2	0	0	0	0	0	6	0	21	6	27	84.00
	9 p. m...	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	8	0	8	74.50
	12 mt...	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	21	65.50
June 12	6 a. m...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58.14
	9 a. m...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68.00
	12 m....	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	81.50
Total.	.....	57	61	69	3	91	30	103	4	89	1	20	0	31	0	5	12	49	2	14	7	528	120	648	.....

m.=noon: mt.=midnight.

TABLE LXXI.—*Time of oviposition by moths of the spring brood; observations taken daily every three hours, except at 3 a. m.; Grand Junction, Colo., 1916; summary of Table LXX.*

Number of observation periods.	Period of observation.	Total number of eggs deposited.	Average number of eggs per oviposition period.	Per cent of eggs deposited per oviposition period.	Mean temperature during oviposition periods.
					°F.
7	12 mt. to 6 a. m.	0	0.00	0.00	57.07
7	6 a. m. to 9 a. m.	0	0.00	0.00	62.64
7	9 a. m. to 12 m.	10	1.42	1.54	76.39
7	12 m. to 3 p. m.	92	13.14	14.20	83.75
7	3 p. m. to 6 p. m.	381	54.42	58.80	82.92
7	6 p. m. to 9 p. m.	133	19.00	20.52	73.14
7	9 p. m. to 12 mt.	32	4.57	4.94	64.96

m=noon; mt=midnight.

Moths of the first brood, 1916.—Oviposition studies, similar to those just described, were made with moths of the first brood during a period of one week from July 24 to 31, inclusive. The results are given in Table LXXII and presented in a summarized form in Table LXXIII.

The eggs were deposited in largest numbers from 3 p. m. to 6 p. m., with the greatest activity about dusk. With a mean temperature of 79.28° F., from 3 p. m. to 6 p. m., over 35 per cent of the eggs were laid, whereas with a lower mean temperature, 72.96° F., from 6 p. m. to 9 p. m., over 46 per cent of the eggs were deposited.

It would appear from the foregoing studies that the time of day is the most influential factor relating to the time of oviposition by moths of the spring and first broods. The moths, as a rule, are most active in depositing their eggs late in the afternoon to early in the evening, their activity being greatest just about dusk.

TABLE LXXII.—*Time of oviposition by moths of the first brood; observations taken daily every three hours except at 3 a. m.; Grand Junction, Colo., 1916.*

Cage No.		1		2		3		4		5		6		7		8		9		10		11		12		13		14		Number of eggs deposited on—		Total number of eggs deposited.	Mean temperature between observations.
Moths emerged July		18		18		19		19		20		20		21		21		21		21		22		22		22		22					
Date of observation.	Time of observation.	Number of eggs deposited on—																															
		Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.		°F.
July 24	3 p. m.	0	0	0	0	0	0	0	4	0	22	0	0	0	23	1	20	0	0	0	0	0	0	0	0	0	0	0	0	1	69	70	94.00
	6 p. m.	1	0	9	3	32	11	19	20	13	8	18	6	1	15	44	22	45	1	64	87	17	0	19	60	10	2	55	58	347	293	640	87.50
	9 p. m.	0	59	29	33	9	21	3	7	16	40	44	52	1	4	44	76	44	33	29	120	5	1	22	56	20	11	38	11	304	524	828	79.00
	12 mt.	47	31	0	3	2	29	21	9	8	14	1	0	2	5	4	6	0	10	0	2	0	0	19	1	22	15	1	1	127	126	253	74.75
25	6 a. m.	3	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	5	8	68.57
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72.75
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	78.00
	3 p. m.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	3	72.75
	6 p. m.	0	8	2	2	11	0	8	4	0	6	16	5	1	9	1	0	6	2	40	24	16	5	15	19	2	1	6	2	124	87	211	75.25
	9 p. m.	38	10	21	3	29	12	0	8	0	5	22	28	0	5	4	4	19	9	9	42	5	1	43	79	20	1	3	5	213	212	425	73.75
	12 mt.	0	0	0	0	0	1	0	1	0	0	5	0	0	0	0	2	0	2	1	3	0	1	0	0	0	0	0	0	6	10	16	71.50
26	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	10	66.85
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	3	68.50
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	29	29	78.50
	3 p. m.	3	0	0	0	0	0	0	0	5	0	5	0	0	0	0	0	6	1	0	7	1	0	3	10	0	0	0	0	23	18	41	76.25
	6 p. m.	0	5	1	2	8	5	3	3	0	14	41	14	1	11	14	17	26	5	28	50	2	0	11	43	32	6	3	6	170	181	351	81.25
	9 p. m.	6	0	9	2	56	0	21	1	1	1	56	1	0	4	26	4	0	1	59	49	69	0	9	23	1	2	12	2	325	90	415	75.75
	12 mt.	2	0	0	0	0	2	2	0	0	1	0	0	0	2	0	0	0	0	1	0	0	1	0	2	0	0	0	0	5	8	13	70.00
27	6 a. m.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	2	3	66.42
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69.25
	12 m.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	2	3	76.00
	3 p. m.	20	7	0	0	1	0	5	0	5	0	7	0	4	0	1	4	0	0	0	1	0	0	2	2	17	0	0	0	62	14	76	80.75
	6 p. m.	0	0	1	0	0	0	0	0	1	0	6	2	0	0	1	1	0	0	0	0	1	0	6	0	2	0	0	2	18	5	23	71.50
	9 p. m.	1	0	0	7	0	0	0	1	2	1	7	1	0	5	0	0	0	0	46	10	1	0	13	6	0	0	17	3	87	34	121	67.50
	12 mt.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	1	0	0	0	0	0	0	0	2	0	0	3	4	7	66.00
28	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64.71
	9 a. m.	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	7	67.50
	12 m.	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	1	9	2	0	0	2	0	0	0	20	3	23	78.25
	3 p. m.	0	0	0	2	5	1	0	0	1	10	6	1	0	0	0	0	0	0	10	0	0	0	0	10	2	0	0	0	24	24	48	84.75

m.=noon; mt.=midnight.

TABLE LXXII.—*Time of oviposition by moths of the first brood; observations taken daily every three hours except at 3 a. m.; Grand Junction, Colo., 1916*—Continued.

Cage No.		1		2		3		4		5		6		7		8		9		10		11		12		13		14		Number of eggs deposited on—		Total number of eggs deposited.	Mean temperature between observations.
Moths emerged July		18		18		19		19		20		20		21		21		21		21		22		22		22		22					
Date of observation.	Time of observation.	Number of eggs deposited on—																															
		Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.	Foliage.	Cage.		°F.
July 28	6 p. m.	1	0	1	1	11	0	1	0	2	1	8	0	0	7	5	4	26	25	20	0	5	0	4	13	17	0	5	7	106	58	164	76.50
	9 p. m.	0	0	0	0	0	0	1	1	2	2	0	0	9	5	0	0	4	3	15	20	3	0	2	12	0	1	2	0	38	44	82	69.50
	12 mt.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	2	66.25
29	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	3	63.85
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65.00
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67.50
	3 p. m.	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	0	0	1	7	0	0	3	0	0	1	0	8	10	18	75.75
	6 p. m.	1	2	0	1	0	7	0	0	0	2	0	0	2	4	0	0	0	0	9	15	1	0	13	18	2	1	3	7	31	57	88	79.50
	9 p. m.	1	0	0	0	3	0	0	0	0	0	0	0	0	0	22	9	0	0	5	8	0	0	0	6	2	0	4	1	37	24	61	73.00
	12 mt.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	66.25
30	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60.71
	9 a. m.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3	3	66.50
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	78.50
	3 p. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	0	5	0	0	0	0	0	10	2	12	87.25
	6 p. m.	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	2	0	0	0	0	0	36	0	5	0	11	0	58	58	83.50
	9 p. m.	0	0	0	0	0	0	0	0	0	0	0	0	5	6	0	0	0	0	4	6	9	7	0	13	7	5	3	1	28	38	66	72.25
	12 mt.	0	0	0	0	3	0	13	0	0	0	2	3	2	0	0	0	2	0	17	0	6	5	6	0	0	3	27	0	78	11	89	72.50
31	6 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67.14
	9 a. m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70.50
	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	2	79.50
	Total	124	125	73	60	177	90	97	60	57	133	255	119	28	110	173	169	180	95	360	456	160	23	194	447	158	57	180	117	2,216	2,061	4,277	.....

m.=noon; mt.=midnight.

TABLE LXXIII.—*Time of oviposition by moths of the first brood, observations taken daily every three hours, except at 3 a. m., Grand Junction, Colo., 1916; summary of Table LXXII.*

Number of observation periods.	Period of observation.	Total number of eggs deposited.	Average number of eggs per oviposition period.	Per cent of eggs deposited per oviposition period.	Mean temperature during oviposition periods.
					°F.
7	12 mt. to 6 a. m....	24	3.42	0.56	65.46
7	6 a. m. to 9 a. m...	13	1.85	0.30	68.57
7	9 a. m. to 12 m....	58	8.28	1.36	76.60
7	12 m. to 3 p. m....	268	38.28	6.27	81.64
7	3 p. m. to 6 p. m..	1,535	219.28	35.92	79.28
7	6 p. m. to 9 p. m..	1,998	285.00	46.68	72.96
7	9 p. m. to 12 mt...	381	54.42	8.91	69.60

m=noon; mt=midnight.

OVIPOSITION BY INDIVIDUAL MOTHS.

Studies of the fecundity of individual moths were made in 1915 and 1916 by isolating pairs of male and female moths in separate cages. These moths were segregated either one or two days after their emergence and were then confined in jelly-glass tumblers into which were placed daily fresh apple or pear foliage and a small piece of sponge moistened with newly made sugar solution. Each cage was examined daily for eggs.

Moths of the first brood, 1915.—As shown in Table LXXIV, the first moths in this study emerged July 26, while the last pair, No. 83, emerged August 19. The summarized results of the observations show that the 83 moths deposited a total of 3,762 eggs, or an average of 45.33 eggs per female. The maximum number of eggs laid by a single individual was 185; the average number of eggs laid by a single female in one day was 10.84 and the maximum 80.

Attention is here drawn to certain facts as revealed by a comparison of Tables XVI and LXXIV. It will be noted in the former table, which gives in detail the oviposition data of moths of the first brood confined, in 1915, in the usual large battery-jar cages, that 46.73 was the average number of eggs deposited per female moth, while 45.33 was the average number deposited per female by the individual caging method, as shown in the latter table. This latter method seems to have reduced the length of the period of oviposition as well as delayed it somewhat. However, as will be seen by a comparison of Tables XVII and LXXIV, the average length of life of the female moth was about the same by either method, it being 12.68 days when the moths were confined in the large battery-jar cages and 12.80 days when caged individually. A detailed record of this and other important oviposition data obtained by the individual caging method in 1915 is given completely in Table LXXIV.

TABLE LXXIV.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1915.*

Pair No.	Date of—				Period (in days).				Total length of life of female moth	Number of days on which oviposition occurred.	Total number of eggs deposited.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
	Emergence of moths.	First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.	Of life of female after oviposition.					
									Days.				
1	July 26	July 28	Aug. 3	Aug. 4	2	7	8	1	9	5	29	5.8	12
2	July 27	July 29	...do.....	Aug. 5	2	6	7	2	9	2	2	1.0	1
3	Aug. 2	Aug. 4	Aug. 10	Aug. 15	2	7	8	5	13	4	31	3.8	24
4	Aug. 4	Aug. 5	Aug. 5	Aug. 8	1	1	1	3	4	1	16	16.0	16
5	...do.....	Aug. 6	Aug. 6	Aug. 16	2	1	2	10	12	1	2	2.0	2
6	...do.....	...do.....	Aug. 14	...do.....	2	9	10	2	12	8	115	14.4	47
7	...do.....	...do.....	Aug. 13	Aug. 17	2	8	9	4	13	4	14	3.5	8
8	...do.....	...do.....	Aug. 11	Aug. 15	2	6	7	4	11	5	121	24.2	38
9	...do.....	...do.....	Aug. 12	...do.....	2	7	8	3	11	6	136	22.7	51
10	...do.....	...do.....	Aug. 9	Aug. 12	2	4	5	3	8	3	19	6.3	10
11	...do.....	...do.....	Aug. 15	Aug. 16	2	10	11	1	12	8	88	11.0	36
12	...do.....	...do.....	Aug. 13	Aug. 17	2	8	9	4	13	8	185	23.1	38
13	...do.....	...do.....	Aug. 16	...do.....	2	11	12	1	13	9	118	13.1	36
14	...do.....	Aug. 7	...do.....	Aug. 19	3	10	12	3	15	2	2	1.0	1
15	...do.....	...do.....	...do.....	...do.....	3	10	12	3	15	7	39	5.6	15
16	...do.....	...do.....	Aug. 11	Aug. 11	3	5	7	0	7	5	95	19.0	26
17	...do.....	Aug. 8	Aug. 13	Aug. 19	4	6	9	6	15	5	77	15.4	44
18	...do.....	...do.....	Aug. 9	Aug. 16	4	2	5	7	12	2	2	1.0	1
19	...do.....	Aug. 10	Aug. 13	...do.....	6	4	9	3	12	4	46	11.5	28
20	Aug. 6	Aug. 8	...do.....	Aug. 14	2	6	7	1	8	6	103	17.2	58
21	...do.....	...do.....	Aug. 9	Aug. 12	2	2	3	3	6	2	30	15.0	27
22	...do.....	...do.....	Aug. 10	Aug. 13	2	3	4	3	7	2	30	15.0	27
23	...do.....	...do.....	...do.....	...do.....	2	3	4	3	7	3	103	34.3	73
24	...do.....	Aug. 9	...do.....	...do.....	3	2	4	3	7	2	5	2.5	3
25	...do.....	Aug. 10	Aug. 18	Aug. 19	4	9	12	1	13	7	22	3.1	6
26	Aug. 7	Aug. 16	Aug. 20	Aug. 21	9	5	13	1	14	4	16	4.0	7
27	...do.....	Aug. 9	Aug. 14	Aug. 17	2	6	7	3	10	4	71	17.8	24
28	...do.....	Aug. 15	Aug. 15	...do.....	8	1	8	2	10	1	3	3.0	3
29	...do.....	Aug. 16	Aug. 16	...do.....	9	1	9	1	10	1	3	3.0	3
30	Aug. 8	Aug. 10	Aug. 17	Aug. 20	2	8	9	3	12	5	25	5.0	9
31	...do.....	...do.....	Aug. 11	Aug. 12	2	2	3	1	4	2	6	3.0	3
32	...do.....	Aug. 11	...do.....	Aug. 19	3	1	3	8	11	1	1	1.0	1
33	...do.....	Aug. 12	Aug. 12	Aug. 16	4	1	4	4	8	1	32	32.0	32
34	Aug. 9	Aug. 11	...do.....	Aug. 19	2	2	3	7	10	2	85	42.5	68
35	...do.....	Aug. 12	Aug. 16	Aug. 20	3	5	7	4	11	3	22	7.3	13
36	...do.....	...do.....	Aug. 22	Aug. 24	3	11	13	2	15	8	121	15.1	30
37	...do.....	...do.....	Aug. 16	Aug. 20	3	5	7	4	11	3	22	7.3	13
38	...do.....	Aug. 13	Aug. 15	Aug. 19	4	3	6	4	10	3	26	8.7	13
39	...do.....	Aug. 14	Aug. 14	Aug. 15	5	1	5	1	6	1	25	25.0	25
40	Aug. 11	...do.....	Aug. 21	Aug. 22	3	8	10	1	11	6	76	12.7	21
41	...do.....	Aug. 15	Aug. 20	...do.....	4	6	9	2	11	6	28	4.7	11
42	...do.....	...do.....	Aug. 15	Aug. 18	4	1	4	3	7	1	15	15.0	15
43	...do.....	...do.....	Aug. 27	Aug. 31	4	13	16	4	20	7	34	4.9	12
44	...do.....	Aug. 16	Aug. 16	Aug. 23	5	1	5	7	12	1	3	3.0	3
45	Aug. 13	Aug. 17	Aug. 23	Aug. 26	4	7	10	3	13	4	7	1.8	3
46	...do.....	...do.....	Sept. 1	Sept. 2	4	16	19	1	20	10	63	6.3	15
47	...do.....	Aug. 18	Aug. 31	Sept. 3	5	14	18	3	21	13	170	13.1	56
48	...do.....	...do.....	Aug. 18	Aug. 22	5	1	5	4	9	1	3	3.0	3
49	...do.....	Aug. 19	Aug. 24	Aug. 26	6	6	11	2	13	4	69	17.3	62
50	...do.....	...do.....	Aug. 29	Aug. 29	6	11	16	0	16	9	158	17.6	63
51	...do.....	Aug. 22	Aug. 27	...do.....	9	6	14	2	16	3	24	8.0	11
52	...do.....	...do.....	Aug. 29	Sept. 1	9	8	16	3	19	3	20	6.7	10
53	...do.....	Aug. 23	Sept. 2	Sept. 8	10	11	20	6	26	8	45	5.6	19
54	...do.....	Aug. 24	Sept. 1	Sept. 2	11	9	19	1	20	4	7	1.8	2
55	...do.....	Aug. 29	Sept. 2	Sept. 3	16	5	20	1	21	4	16	4.0	6
56	...do.....	Aug. 30	Aug. 30	Aug. 31	17	1	17	1	18	1	4	4.0	4
57	...do.....	Aug. 19	Aug. 23	Aug. 27	6	5	10	4	14	4	63	15.8	50
58	...do.....	Aug. 20	Aug. 20	...do.....	7	1	7	7	14	1	5	5.0	5
59	Aug. 15	Aug. 18	Aug. 22	Aug. 26	3	5	7	4	11	5	120	24.0	37
60	...do.....	...do.....	...do.....	...do.....	3	5	7	4	11	5	90	18.0	28
61	...do.....	...do.....	Aug. 24	Aug. 31	3	7	9	7	16	3	9	3.0	7
62	...do.....	Aug. 19	Aug. 28	Aug. 29	4	10	13	1	14	9	101	11.2	39
63	...do.....	Aug. 20	Aug. 20	Aug. 22	5	1	5	2	7	1	13	13.0	13
64	...do.....	...do.....	Aug. 27	Sept. 1	5	8	12	5	17	6	30	5.0	9
65	...do.....	Aug. 23	Aug. 24	...do.....	8	2	9	8	17	2	6	3.0	5
66	Aug. 19	Aug. 22	Aug. 25	Aug. 27	3	4	6	2	8	3	29	9.7	24
67	...do.....	...do.....	Aug. 26	...do.....	3	5	7	1	8	4	123	30.8	80
68	...do.....	...do.....	Aug. 23	Aug. 29	3	2	4	6	10	2	17	8.5	16
69	...do.....	...do.....	Sept. 4	Sept. 5	3	13	16	1	17	10	110	11.0	41

TABLE LXXIV.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1915*—Continued.

Pair No.	Date of—				Period (in days).				Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs deposited.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
	Emergence of moths.	First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.	Of life of female after oviposition.					
									Days.				
70	Aug. 19	Aug. 22	Aug. 30	Aug. 31	3	9	11	1	12	8	82	10.3	50
71	...do.....	...do.....	Aug. 25	...do.....	3	4	6	6	12	4	83	20.8	46
72	...do.....	Aug. 23	Aug. 29	Sept. 1	4	7	10	3	13	4	27	6.8	12
73	...do.....	...do.....	Aug. 30	Aug. 31	4	8	11	1	12	6	55	9.2	19
74	...do.....	Aug. 25	Sept. 1	Sept. 2	6	8	13	1	14	3	19	6.3	9
75	...do.....	...do.....	Aug. 29	Sept. 1	6	5	10	3	13	5	32	6.4	9
76	...do.....	Aug. 26	...do.....	Aug. 31	7	4	10	2	12	3	18	6.0	11
77	...do.....	...do.....	...do.....	Sept. 1	7	4	10	3	13	2	12	6.0	10
78	...do.....	Aug. 27	Sept. 7	Sept. 10	8	12	19	3	22	8	24	3.0	5
79	...do.....	Aug. 28	...do.....	Sept. 8	9	11	19	1	20	6	30	5.0	10
80	...do.....	Aug. 29	Aug. 31	Sept. 2	10	3	12	2	14	2	8	4.0	5
81	...do.....	Sept. 1	Sept. 1	Sept. 8	13	1	13	7	20	1	9	9.0	9
82	...do.....	...do.....	Sept. 9	Sept. 12	13	9	21	3	24	4	13	3.3	7
83	...do.....	Sept. 2	Sept. 2	Sept. 5	14	1	14	3	17	1	4	4.0	4
	Total.									347	3,762		

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days from emergence to first oviposition	4.90	17	1
Number of days from emergence to last oviposition	9.66	21	1
Number of days in period during which female was depositing eggs	5.75	16	1
Number of days on which oviposition occurred	4.18	13	1
Number of days female moth lived after last oviposition	3.12	10	0
Total length of life of female moth in days	12.80	26	4
Number of eggs deposited by one female moth	45.33	185	1
Number of eggs deposited by one female moth in one day	10.84	80	0

In Table LXXV it will be noted that 14 moths have an oviposition record of 100 or more eggs, one having laid 185 eggs, two over 150 eggs, one over 125, and ten between 100 and 125 eggs.

TABLE LXXV.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1915; data taken from Table LXXIV.*

Number of eggs deposited by individual moths.			
100 to 125	125 to 150	150 to 175	175 to 200
101	136	158	185
103		170	
103			
110			
115			
118			
120			
121			
121			
123			

Moths of the first brood, 1916.—The study of the number of eggs deposited by moths of the first brood was continued in 1916 on a more extensive scale than during the preceding year. The methods employed, however, were identical in all respects. The data herewith given were obtained by recording daily the number of eggs laid by 201 female moths, beginning with moths that emerged July 11 and ending with moths that issued August 22. As will be seen in Table LXXVI, these 201 individuals deposited a total of 17,225 eggs, or an average of 85.70 eggs per female.

TABLE LXXVI.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1916.*

Pair No.	Date of—				Period (in days).				Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs deposited.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
	Emergence of moths.	First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.	Of life of female after oviposition.					
									Days.				
1	July 11	July 13	July 22	July 23	2	10	11	1	12	9	229	25.4	57
2	...do....	July 14	July 21	July 22	3	8	10	1	11	5	109	21.8	38
3	...do.....	July 19	July 25	July 27	8	7	14	2	16	5	15	3.0	6
4	...do.....	...do.....	July 23	July 28	8	5	12	5	17	5	48	9.6	29
5	...do.....	.....	.....	July 16	....	....	.....	.....	5	.....	0	.....	.....
6	...do.....	July 20	July 20	July 23	9	1	9	3	12	1	3	3.0	3
7	July 12	July 17	July 23	July 26	5	7	11	3	14	7	185	26.4	67
8	...do.....	July 15	...do.....	July 30	3	9	11	7	18	8	192	24.0	45
9	...do.....	July 14	July 14	July 24	2	1	2	10	12	1	39	39.0	39
10	...do.....	July 21	July 21	July 26	9	1	9	5	14	1	6	6.0	6
11	...do.....	July 19	July 23	...do.....	7	5	11	3	14	3	5	1.7	3
12	...do.....	.....	.....	(1)	....	....	.....	.....	.....	.....	0	.....	.....
13	July 13	July 23	July 29	July 30	10	7	16	1	17	5	12	2.4	6
14	...do.....	July 18	July 26	July 28	5	9	13	2	15	9	186	20.7	66
15	...do.....	...do.....	July 25	...do.....	5	8	12	3	15	8	55	6.9	27
16	...do.....	July 15	July 27	July 27	2	13	14	0	14	13	199	15.3	64
17	...do.....	...do.....	July 20	July 21	2	6	7	1	8	6	107	17.8	36
18	...do.....	...do.....	July 21	(1)	2	7	8	.....	.....	7	185	26.4	54
19	...do.....	July 16	...do.....	July 25	3	6	8	4	12	5	127	25.4	54
20	...do.....	...do.....	July 18	...do.....	3	3	5	7	12	3	146	48.7	77
21	...do.....	.....	.....	Aug. 5	....	....	.....	.....	23	.....	0	.....	.....
22	...do.....	July 29	July 29	July 29	16	1	16	0	16	1	1	1.0	1
23	July 14	July 16	July 21	July 22	2	6	7	1	8	6	159	26.5	48
24	...do.....	July 22	July 29	July 30	8	8	15	1	6	4	9	2.3	4
25	...do.....	July 23	...do.....	...do.....	9	7	15	1	6	5	46	9.2	21
26	...do.....	July 16	July 31	Aug. 1	2	16	17	1	18	8	89	11.1	45
27	...do.....	...do.....	July 29	July 29	2	14	15	0	15	11	69	6.3	10
28	...do.....	July 18	...do.....	...do.....	4	12	15	0	15	10	245	24.5	74
29	...do.....	July 16	Aug. 1	Aug. 2	2	17	18	1	19	10	58	5.8	22
30	...do.....	.....	.....	July 17	....	....	.....	.....	3	.....	0	.....	.....
31	...do.....	.....	.....	July 25	....	....	.....	.....	11	.....	0	.....	.....
32	July 15	July 17	July 22	July 30	2	6	7	8	15	5	99	19.8	40
33	...do.....	July 20	July 20	July 20	5	1	5	0	5	1	8	8.0	8
34	...do.....	July 17	July 27	July 28	2	11	12	1	13	11	266	24.2	78
35	...do.....	July 18	July 30	July 30	3	13	15	0	15	13	168	12.9	48
36	...do.....	July 19	Aug. 3	Aug. 4	4	16	19	1	20	7	21	3.0	8
37	...do.....	July 31	Aug. 5	Aug. 7	16	6	21	2	23	6	20	3.3	8
38	...do.....	July 18	July 30	July 31	3	13	15	1	16	11	207	18.8	51
39	...do.....	July 22	Aug. 5	Aug. 6	7	15	21	1	22	13	77	5.9	18
40	...do.....	.....	.....	July 17	....	....	.....	.....	2	.....	0	.....	.....
41	...do.....	July 24	Aug. 7	Aug. 9	9	15	23	2	25	3	3	1.0	1
42	July 16	July 18	July 29	Aug. 1	2	12	13	3	16	5	120	24.0	76
43	...do.....	...do.....	July 24	July 30	2	7	8	6	14	4	7	1.8	3
44	...do.....	July 22	Aug. 3	Aug. 3	6	13	18	0	18	13	271	20.8	54
45	...do.....	July 18	July 23	July 25	2	6	7	2	9	6	151	25.2	87
46	...do.....	July 23	July 30	Aug. 1	7	8	14	2	16	7	113	16.1	45
47	...do.....	July 22	Aug. 1	...do.....	6	11	16	0	16	5	8	1.6	3
48	...do.....	July 20	Aug. 15	Aug. 16	4	27	30	1	31	14	35	2.5	6

[1] Date of death unknown.

TABLE LXXVI.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1916*—Continued.

Pair No.	Date of—				Period (in days).				Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs deposited.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
	Emergence of moths.	First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.	Of life of female after oviposition.					
									Days.				
49	July 16	July 19	July 31	Aug. 1	3	13	15	1	16	11	119	10.8	31
50	...do.....	.....	.....	July 29	....	....	.....	.....	13	.....	0	.....	.....
51	July 17	July 24	July 31	July 1	7	8	14	1	15	8	67	8.4	20
52	...do.....	July 23	Aug. 2	July 2	6	11	16	0	16	10	128	12.8	71
53	...do.....	July 20	July 30	July 1	3	10	13	2	15	8	95	11.9	31
54	...do.....	July 19	July 28	July 29	2	10	11	1	12	10	213	21.3	47
55	...do.....	July 22	Aug. 2	Aug. 2	5	12	16	0	16	10	175	17.5	81
56	...do.....	July 19	July 27	July 30	2	9	10	3	13	9	258	28.7	81
57	...do.....	July 22	Aug. 4	Aug. 4	5	14	18	0	18	12	90	7.5	16
58	...do.....	July 21	July 31	July 31	4	11	14	0	14	11	195	17.7	51
59	...do.....	July 19	July 28	July 30	2	10	11	2	13	8	121	15.1	61
60	...do.....	July 23	July 27	Aug. 1	6	5	10	5	15	2	2	1.0	1
61	July 18	July 20	July 30	Aug. 2	2	11	12	3	15	11	215	19.5	62
62	...do.....	...do.....	...do.....	July 31	2	11	12	1	13	10	126	12.6	28
63	...do.....	July 22	Aug. 6	Aug. 7	4	16	19	1	20	9	101	1.1	56
64	...do.....	...do.....	July 31	Aug. 2	4	10	13	2	15	9	139	15.4	58
65	...do.....	July 20	July 29	July 29	2	10	11	0	11	10	236	23.6	69
66	...do.....	July 22	July 31	Aug. 2	4	10	13	2	15	9	183	20.3	69
67	...do.....	...do.....	Aug. 1	Aug. 4	4	11	14	3	17	4	5	1.3	2
68	...do.....	...do.....	July 22	July 26	4	1	4	4	8	1	2	2.0	2
69	...do.....	July 26	July 26	Aug. 2	8	1	8	7	15	1	1	1.0	1
70	July 19	July 21	July 31	...do.....	2	11	12	2	14	5	22	4.4	8
71	...do.....	July 28	Aug. 6	Aug. 7	9	10	18	1	19	8	56	7.0	20
72	...do.....	July 22	July 31	Aug. 1	3	10	12	1	13	10	165	16.5	37
73	...do.....	July 28	Aug. 2	Aug. 5	9	6	14	3	17	4	20	5.0	7
74	...do.....	July 24	July 30	July 30	5	7	11	0	11	7	126	18.0	27
75	...do.....	July 28	Aug. 3	Aug. 4	9	7	15	1	16	6	98	16.3	38
76	...do.....	.....	.....	July 29	....	....	.....	.....	10	.....	0	.....	.....
77	...do.....	Aug. 2	Aug. 2	Aug. 9	14	1	14	7	21	1	2	2.0	2
78	...do.....	.....	.....	Aug. 3	....	....	.....	.....	15	.....	0	.....	.....
79	July 20	July 24	Aug. 5	Aug. 6	4	13	16	1	17	9	223	24.8	111
80	...do.....	July 25	Aug. 9	Aug. 14	5	16	20	5	25	9	20	2.2	5
81	...do.....	July 24	Aug. 4	Aug. 4	4	12	15	0	15	10	55	5.5	15
82	...do.....	July 22	Aug. 5	Aug. 7	2	15	16	2	18	10	200	20.0	109
83	...do.....	July 25	July 30	July 30	5	6	10	0	10	6	165	27.5	44
84	...do.....	July 23	...do.....	Aug. 1	3	8	10	2	12	8	252	31.5	89
85	...do.....	July 22	Aug. 6	Aug. 9	2	16	17	3	20	9	29	3.2	9
86	July 21	...do.....	July 29	July 30	1	8	8	1	9	6	102	17.0	47
87	...do.....	July 23	July 30	Aug. 5	2	8	9	6	15	6	91	15.2	40
88	...do.....	July 31	Aug. 8	Aug. 9	10	9	18	1	19	9	181	20.1	50
89	...do.....	July 25	Aug. 17	Aug. 18	4	24	27	1	28	20	136	6.8	22
90	...do.....	.....	.....	July 28	....	....	.....	.....	7	.....	0	.....	.....
91	Aug. 5	Aug. 7	Aug. 24	Aug. 25	2	18	19	1	20	17	316	18.6	112
92	Aug. 6	...do.....	Aug. 17	Aug. 18	1	11	11	1	12	11	240	21.8	52
93	...do.....	Aug. 14	Aug. 28	Aug. 29	8	15	22	1	23	12	249	20.8	106
94	...do.....	Aug. 11	...do.....	Sept. 1	5	18	22	4	26	7	13	1.9	3
95	...do.....	Aug. 14	Aug. 21	Aug. 23	8	8	15	2	17	8	175	21.9	69
96	...do.....	...do.....	Aug. 17	...do.....	8	4	11	6	17	3	21	7.0	19
97	...do.....	Aug. 8	Aug. 14	Aug. 20	2	7	8	6	14	6	88	14.7	47
98	...do.....	.....	.....	Aug. 23	....	....	.....	.....	17	.....	0	.....	.....
99	...do.....	Aug. 8	Aug. 19	Aug. 19	2	12	13	0	13	2	2	1.0	1
100	...do.....	.....	.....	Aug. 13	....	....	.....	.....	7	.....	0	.....	.....
101	...do.....	Aug. 19	Aug. 19	Sept. 4	13	1	13	16	29	1	2	2.0	2
102	Aug. 8	Aug. 10	Aug. 27	(1)	2	18	19	.....	.....	8	56	7.0	18
103	...do.....	Aug. 12	Aug. 23	Aug. 24	4	12	15	1	16	11	39	3.5	12
104	...do.....	Aug. 11	Aug. 17	Aug. 20	3	7	9	3	12	7	158	22.6	49
105	...do.....	Aug. 15	Aug. 22	Aug. 24	7	8	14	2	16	5	8	1.6	2
106	...do.....	Aug. 14	Aug. 16	Aug. 18	6	3	8	2	10	3	133	44.3	115
107	...do.....	Aug. 25	Sept. 4	Sept. 5	17	11	27	1	28	2	3	1.5	2
108	...do.....	Aug. 12	Aug. 18	Aug. 21	4	7	10	3	13	2	4	2.0	3
109	Aug. 9	Aug. 17	Aug. 19	Aug. 22	8	3	10	3	13	3	7	2.3	4
110	...do.....	...do.....	...do	Aug. 19	8	3	10	0	10	3	20	6.7	10
111	...do.....	Aug. 18	Aug. 31	(1)	9	14	22	.....	.....	10	29	2.9	6
112	...do.....	Aug. 11	Sept. 5	Sept. 11	2	26	27	6	33	16	74	4.6	17
113	...do.....	...do.....	Aug. 29	Aug. 30	2	19	20	1	21	18	227	12.6	25
114	...do.....	...do.....	Aug. 23	Aug. 24	2	13	14	1	15	6	22	3.7	13

[1] Date of death unknown.

TABLE LXXVI.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1916*—Continued.

Pair No.	Date of—				Period (in days).				Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs deposited.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
	Emergence of moths.	First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.	Of life of female after oviposition.					
									Days.				
115	Aug. 9	Aug. 14	Aug. 28	Sept. 2	5	15	19	5	24	14	116	8.3	22
116	...do.....	Aug. 11	Aug. 30	Aug. 31	2	20	21	1	22	19	88	4.6	9
117	...do.....	Aug. 16	Aug. 16	Aug. 24	7	1	7	8	15	1	1	1.0	1
118	...do.....	.....	.....	Aug. 22	.....	.....	.....	.....	13	.....	0	.....	.....
119	Aug. 10	Aug. 16	Aug. 28	Aug. 29	6	13	18	1	19	11	188	17.1	54
120	...do.....	Aug. 12	Aug. 25	Aug. 25	2	14	15	0	15	10	112	11.2	44
121	...do.....	Aug. 15	Aug. 23	Aug. 29	5	9	13	6	19	8	142	17.8	43
122	...do.....	Aug. 23	Aug. 31	Sept. 2	13	9	21	2	23	6	50	8.3	31
123	...do.....	Aug. 18	Aug. 19	Sept. 3	8	2	9	15	24	2	3	2.5	2
124	...do.....	.....	.....	Aug. 26	.....	.....	.....	.....	16	.....	0	.....	.....
125	...do.....	.....	.....	Aug. 25	.....	.....	.....	.....	15	.....	0	.....	.....
126	...do.....	Aug. 17	Aug. 24	Aug. 30	7	8	14	6	20	3	4	1.3	2
127	...do.....	Aug. 25	Aug. 31	(1)	15	7	21	.....	.....	4	7	1.8	3
128	...do.....	Aug. 18	Aug. 19	Aug. 30	8	2	9	11	20	2	6	3.0	4
129	Aug. 11	Aug. 12	Aug. 27	Aug. 27	1	16	16	0	16	13	133	10.2	51
130	...do.....	Aug. 15	Sept. 8	Sept. 11	4	25	28	3	31	24	210	8.8	37
131	...do.....	Aug. 19	Aug. 29	Aug. 31	8	11	18	2	20	8	27	3.4	10
132	...do.....	Aug. 17	Aug. 25	Aug. 26	6	9	14	1	15	6	65	10.8	22
133	...do.....	...do.....	Sept. 13	Sept. 13	6	28	33	0	33	24	139	5.8	15
134	...do.....	Sept. 2	Sept. 11	...do....	22	10	31	2	33	5	6	1.2	2
135	...do.....	Aug. 14	Sept. 3	Sept. 6	3	21	23	3	26	18	251	13.9	39
136	...do.....	Aug. 15	Sept. 9	Sept. 13	4	26	29	4	33	22	116	5.3	13
137	...do.....	Aug. 14	Aug. 14	Aug. 22	3	1	3	8	11	1	2	2.0	2
138	...do.....	.....	.....	Aug. 23	.....	.....	.....	.....	12	.....	0	.....	.....
139	Aug. 13	Aug. 16	Aug. 21	...do....	3	6	8	2	10	3	82	27.3	49
140	...do.....	Aug. 15	Aug. 28	(1)	2	14	15	.....	.....	12	213	17.8	34
141	...do.....	...do.....	Aug. 24	Aug. 26	2	10	11	2	13	9	144	16.0	34
142	...do.....	Aug. 16	Aug. 29	Aug. 30	3	14	16	1	17	10	120	12.0	33
143	...do.....	Aug. 18	Aug. 26	Aug. 31	5	9	13	5	18	7	103	14.7	72
144	...do.....	Aug. 15	Aug. 18	Aug. 19	2	4	5	1	6	4	61	15.3	33
145	...do.....	Aug. 18	Aug. 25	Aug. 25	5	8	12	0	12	7	163	23.3	41
146	...do.....	Aug. 23	Aug. 23	Aug. 24	10	1	10	1	11	1	2	2.0	2
147	...do.....	Aug. 28	Aug. 28	Sept. 8	15	1	15	11	26	1	2	2.0	2
148	...do.....	Aug. 17	Aug. 19	Aug. 24	4	3	16	5	11	2	2	1.0	1
149	Aug. 14	Aug. 15	Sept. 3	Sept. 4	1	20	20	1	21	9	28	3.1	8
150	...do.....	Aug. 18	Aug. 25	Aug. 26	4	8	11	1	12	3	10	3.3	5
151	...do.....	Aug. 22	Aug. 27	Aug. 28	8	6	13	1	14	5	43	8.6	18
152	...do.....	Aug. 17	...do....	...do....	3	11	13	1	14	11	227	20.6	71
153	...do.....	Aug. 16	Sept. 6	Sept. 11	2	22	23	5	28	21	308	14.7	52
154	...do.....	Aug. 17	Aug. 27	Sept. 3	3	11	13	7	20	7	80	11.4	41
155	...do.....	Aug. 18	Aug. 31	(1)	4	14	17	.....	.....	13	223	17.2	45
156	...do.....	Aug. 21	Sept. 1	Sept. 2	7	12	18	1	19	10	99	9.9	20
157	...do.....	Aug. 19	Aug. 19	Aug. 20	5	1	5	1	6	1	3	3.0	3
158	...do....	.....	.....	Aug. 30	.....	.....	.....	.....	16	.....	0	.....	.....
159	Aug. 15	Aug. 17	Aug. 31	Sept. 2	2	15	16	2	18	15	252	1.7	41
160	...do.....	Aug. 18	Aug. 21	Aug. 25	3	4	6	4	10	4	33	8.3	19
161	...do.....	...do.....	Aug. 29	(1)	3	12	14	.....	.....	10	186	18.6	59
162	...do.....	Aug. 23	Sept. 3	Sept. 5	8	12	19	2	21	7	17	2.4	8
163	...do.....	Aug. 18	Aug. 18	Aug. 21	3	1	3	3	6	1	8	8.0	8
164	...do.....	...do....	Aug. 20	Aug. 26	3	3	5	6	11	3	21	7.0	10
165	...do.....	Aug. 17	Aug. 28	Aug. 29	2	12	13	1	14	11	221	2.0	60
166	...do.....	Aug. 19	Aug. 31	Sept. 1	4	13	16	1	17	4	6	1.5	3
167	...do.....	Aug. 24	Aug. 29	Sept. 2	9	6	14	4	18	3	6	2.0	3
168	...do.....	Aug. 21	Aug. 21	Sept. 1	6	1	6	11	17	1	1	1.0	1
169	Aug. 16	Aug. 27	Sept. 1	Sept. 6	11	6	16	5	21	5	10	2.0	4
170	...do.....	Aug. 26	Sept. 3	Sept. 4	10	9	18	1	19	5	16	3.2	7
171	...do.....	Aug. 18	Aug. 24	Aug. 28	2	7	8	4	12	4	134	33.5	89
172	...do.....	Aug. 27	Aug. 28	Sept. 2	11	2	12	5	17	2	2	1.0	1
173	...do.....	Aug. 30	Aug. 30	Sept. 1	14	1	14	2	16	1	1	1.0	1
174	...do.....	Aug. 26	Aug. 28	...do.....	10	3	12	4	16	2	4	2.0	3
175	...do.....	.....	.....	Aug. 24	.....	.....	.....	.....	8	.....	0	.....	.....
176	Aug. 18	Aug. 21	Aug. 31	(1)	3	11	13	.....	.....	11	277	25.2	59
177	...do.....	Aug. 20	Aug. 28	Aug. 29	2	9	10	1	11	9	168	18.7	68
178	...do.....	Aug. 25	Aug. 29	Sept. 10	7	5	11	12	23	2	2	1.0	1
179	...do.....	Aug. 20	...do....	Sept. 1	2	10	11	3	14	9	71	7.9	18
180	...do.....	.....	.....	Sept. 4	.....	.....	.....	.....	17	.....	0	.....	.....
181	...do.....	Aug. 24	Aug. 31	Sept. 1	6	8	13	1	14	3	3	1.0	1
182	...do.....	Aug. 25	Aug. 27	Sept. 2	7	3	9	6	15	2	3	1.5	2

[1] Date of death unknown.

TABLE LXXVI.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1916*—Continued.

Pair No.	Date of—				Period (in days).				Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs deposited.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
	Emergence of moths.	First oviposition.	Last oviposition.	Death of female moth.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.	Of life of female after oviposition.					
									Days.				
183	Aug. 21	Aug. 24	Sept. 9	Sept. 9	3	17	19	0	19	14	247	17.6	46
184	...do.....	...do.....	Sept. 14	(1)	3	22	24	.....	.....	20	135	6.8	20
185	...do.....	...do.....	Sept. 8	Sept. 10	3	16	18	2	20	14	309	22.1	76
186	...do.....	Aug. 26	Sept. 3	Sept. 12	5	9	13	9	22	6	13	2.2	4
187	...do.....	Aug. 24	Sept. 2	Sept. 3	3	10	12	1	13	7	80	11.3	28
188	...do.....	...do.....	Sept. 4	Sept. 6	3	12	14	2	16	5	12	2.4	4
189	...do.....	Aug. 26	Sept. 17	Sept. 18	5	23	27	1	28	16	50	3.1	7
190	...do.....	Aug. 25	Sept. 8	Sept. 11	4	15	18	3	21	8	21	2.6	5
191	...do.....	Aug. 22	Aug. 29	Sept. 5	1	8	8	7	15	7	87	12.4	29
192	Aug. 22	Aug. 24	Sept. 24	Sept. 25	2	32	33	1	34	31	203	6.5	17
193	...do.....	Aug. 31	Sept. 15	Sept. 18	9	16	24	3	27	11	33	3.0	13
194	...do.....	Aug. 26	Sept. 25	Sept. 30	4	31	34	5	39	19	47	2.5	9
195	...do	Aug. 30	Sept. 13	Sept. 17	8	15	22	4	26	10	42	4.2	14
196	...do	Aug. 25	Aug. 30	Aug. 31	3	6	8	1	9	6	157	26.2	63
197	...do	Sept. 2	Sept. 11	Sept. 14	11	10	20	3	23	7	118	16.9	55
198	...do	Aug. 28	Sept. 22	Sept. 25	6	26	31	3	34	21	182	8.7	64
199	...do.....	Aug. 27	Sept. 12	Sept. 13	5	17	21	1	22	12	29	2.4	5
200	...do.....	Aug. 24	Sept. 1	Sept. 5	2	9	10	4	14	5	9	1.8	3
201	...do.....	Aug. 28	...do	...do	6	5	10	4	14	4	32	8.0	8
	Total	.....	.....	.....	.....	.....	.....	.....	.....	1,467	17,225	.....	.....

[1] Date of death unknown.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days from emergence to first oviposition	5.19	22	1
Number of days from emergence to last oviposition	14.47	34	2
Number of days in period during which female was depositing eggs	10.26	32	1
Number of days on which oviposition occurred	8.06	31	1
Number of days female moth lived after last oviposition	2.80	16	0
Total length of life of female moth in days	16.42	39	3
Number of eggs deposited by one female moth	85.70	316	0
Number of eggs deposited by one female moth in one day	11.74	115	0

It will be noted also in this table that the female moth of pair No. 91 deposited 316 eggs, which is, so far as the writers are aware, the highest number of eggs ever recorded from one individual codling moth. This moth was seen in copula on August 7, or two days after issuance, and two days later, August 9, deposited 112 eggs, or over one-third of her total. Another moth, of pair No. 106, emerged August 8, but did not deposit an egg until August 14, on this date laying 115 eggs. This is believed to be the highest recorded number of eggs deposited in one day by an individual codling moth. In addition to this moth several other females deposited over 100 eggs in one day, the average being 11.74.

A comparison of Tables XLII and LXXVI will show that the average number of eggs per female was greater in 1916, but that, as in 1915, the period of oviposition was shortened somewhat and that it was also delayed where the pairs were confined alone in individual cages. However, in 1916, the female lived for an average of 12.20 days when confined with other moths in a large battery-jar cage, as shown in Table XLIII, compared with 16.42 days when caged individually. Other important phases of the individual oviposition studies of 1916 are given in detail in Table LXXVI.

An abbreviated table giving the data for all of the moths that deposited 100 or more eggs is given herewith. (See Table LXXVII.) Referring to this table, it will be noted that 3 moths deposited over 300 eggs each, 1 moth deposited between 275 and 300 eggs, 6 moths between 250 and 275 eggs, 8 moths between 225 and 250 eggs, 10 moths between 200 and 225 eggs, 13 moths between 175 and 200 eggs, 9 moths between 150 and 175 eggs, 14 moths between 125 and 150 eggs, and 14 moths between 100 and 125 eggs.

TABLE LXXVII.—*Oviposition by individual codling moths of the first brood, Grand Junction, Colo., 1916. Data taken from Table LXXVI.*

Number of eggs deposited.								
100 to 125	125 to 150	150 to 175	175 to 200	200 to 225	225 to 250	250 to 275	275 to 300	300 to 325
101	126	151	175	200	227	251	277	308
102	126	157	175	203	227	252		309
103	127	158	181	207	229	252		316
107	128	159	182	210	236	258		
109	133	163	183	213	240	266		
112	133	165	185	213	245	271		
113	134	165	185	215	247			
116	135	168	186	221	249			
116	136	168	186	223				
118	139		188	223				
119	139		192					
120	142		195					
120	144		199					
121	146							

DEPOSITION OF INFERTILE EGGS.

On July 15, 1915, 30 female moths of the first brood which emerged on this day were confined alone in a cage to find the number of eggs deposited when male moths were not present. The results are given in Table LXXVIII, in which it will be seen that a total of 232 eggs were deposited, or an average of 7.40 eggs per moth.

TABLE LXXVIII.—*Deposition of infertile codling moth eggs, Grand Junction, Colo., 1915 (30 female moths emerged July 15).*

Number of eggs deposited.	Date of deposition.	Number of dead moths.	Date of death of moths.
2	July 18	1	July 21
3	19	3	23
30	20	5	24
16	21	1	25
8	22	3	26
42	23	1	27
31	24	2	28
4	26	1	29
40	27	3	30
6	28	2	31
12	29	2	Aug. 1
35	30	1	2
3	Aug. 1	3	3
		1	4
		1	5
232	.....	30	.....

TIME REQUIRED FOR CODLING-MOTH LARVA TO LEAVE THE EGG.

The following notes were made July 30, 1915, on the time required for a codling-moth larva to leave the egg.

Egg No. 1.—At 1.10 p. m. there was a small rent in the chorion and at 1.50 p. m. the larva had completely left the eggshell.

Egg No. 2.—At 1.15 p. m. the larva had cut a small opening in the eggshell, and had hatched by 1.23 p. m.

Egg No. 3.—At 1.20 p. m. the larva was found moving its body and mandibles intermittently until 2.03 p. m. It hatched at 2.06 p. m.

Egg No. 4.—The eggshell was found slightly opened at 2.09 p. m. The larva hatched at 2.13 p. m.

Egg No. 5.—This egg was slightly open at 2.18 p. m., and although the larva made repeated attempts to extricate itself it did not accomplish its task until 2.55 p. m.

As previously stated, the codling-moth larva normally tears a small opening in the eggshell by means of its mandibles and then passes out of the shell head foremost.

LARVÆ THAT FAIL TO EXTRICATE THEMSELVES FROM THE CHORION.

On several occasions larvæ were found dead after having partially extricated themselves from the chorion. In these instances it was noted that the anal end was protruding through the cut in the eggshell, but that the larva was held from freeing itself on account of the cervical shield and head, which were too large to pass through the opening. Normally, as previously mentioned, the larva tears a slit in the eggshell by means of its mandibles and then passes head first through the rent.

HABITS OF NEWLY HATCHED LARVÆ.

The natural instinct of newly-hatched insect larvæ is to seek suitable food on which to commence feeding. In the case of the codling moth the fruit of the apple and pear is the preferred food, but the larvæ will also attack the foliage and occasionally will burrow into the tips of tender twigs. The injury to the foliage is of little consequence, consisting of small holes through the lower epidermis, usually where the leaf is fleshy, as at the junction of the veins with the midrib.

The frequency and amount of foliage feeding depend mainly on the distance of the eggs from the fruit and the ease with which the larvæ find their ultimate object. Normally the early-season eggs are deposited upon the whorl of leaves about the fruit, while later in the year many eggs are laid directly on the fruit. It has been observed that some larvæ spend considerable time before they reach the fruit and that these satisfy their appetites on the foliage during the interim.

Upon reaching the fruit, the larvæ seek a place of entrance, as through the calyx, side, or stem. (See Pl. VI, A.) Some individuals crawl over the fruit for some little time before making an attack, while others proceed to enter with little hesitation. The larvæ will frequently take advantage of depressions or ruptures in the skin, as frost pits, hail marks, or injury from other causes.

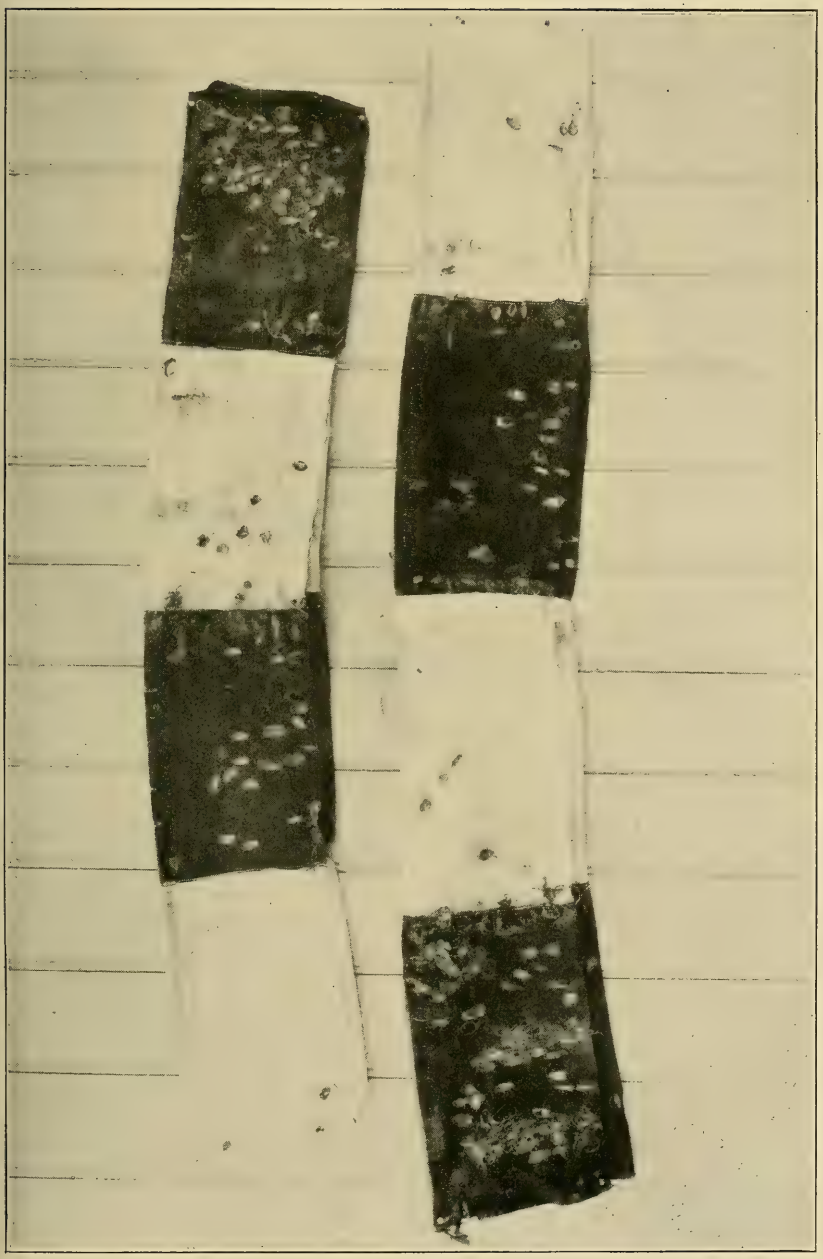
The larvæ, in starting to feed, tear away the skin by means of their mandibles and cast most of it aside, consuming very little. They first work directly beneath the skin, forming a shallow excavation just large enough to accommodate them, and at the same time, plug their entrance with frass.

THE CODLING-MOTH "STING."

The so-called "sting" is caused by the larvæ that succumb to the poison before they are able to make more than the shallow excavation above referred to. They sometimes die from natural causes after having penetrated beneath the skin and occasionally they leave an entrance hole to start a new one.

CODLING-MOTH LARVÆ FEEDING ON PEAR TWIGS.

On June 24, 1915, an examination of a pear orchard was made to determine the cause of the browning of the leaves. At first sight the orchard appeared to be affected with pear blight, *Bacillus amylovorus* (Burrill) De Toni, but on closer inspection it was found that codling-moth larvæ were responsible for the injury. There was practically no fruit in the orchard, owing to the spring freezes, and, as a result, the larvæ burrowed into the terminal ends of the twigs to a



BLACK AND WHITE BANDS SHOWING THAT LARVÆ PREFER TO FORM COCOONS BENEATH THE BLACK CLOTH.

THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO.

distance of about three-fourths inch. In many of the burrows no larvæ were found, they evidently having decided to leave after they had consumed most of the softer tissue of the new growth. The larvæ found were in either the third or fourth instars. An attempt was made to rear some of these larvæ in pear twigs, but this was unsuccessful. Two of the larvæ obtained from the pear twigs, however, were transferred to apples on the date collected, June 24, and from these two moths were reared, one moth issuing on July 19 and the other on July 20.

EXPERIMENTS WITH BLACK AND WHITE BANDS.

In fruit districts where the codling moth is abundant, spraying is frequently supplemented with banding. With the banding method a strip of cloth is placed around the trunk of the tree and the codling-moth larvæ that form cocoons beneath the cloth are destroyed at intervals of about 10 days throughout the season. The question has frequently been asked whether dark-colored bands are more attractive as a place of concealment than bands of a light color. To determine this, an experiment was made in 1916 in which were used bands of cloth folded to three thicknesses, each alternate quarter of which was black and white. (See Pl. VII.) The trunks of 10 trees were first thoroughly scraped and were then encircled with bands of this description on July 5. The segments of the bands were arranged so that the white and black quarters alternated with the four quarters of the trunk. Thus on 5 trees there was a black segment on the northeast side of the tree, while on the 5 remaining trees there was a white segment covering this quarter. The bands were first examined for larvæ on July 8 and every 3 days thereafter to August 19, inclusive. The results of this study are given in Table LXXIX, in which it will be seen that the codling-moth larva is strongly inclined, when the opportunity is present, to spin its cocoon beneath dark-colored cloth. Out of a total of 2,362 larvæ collected, 2,083, or 88.19 per cent, spun their cocoons beneath the black segments of the bands. A summary of this table is given in Table LXXX, which shows the number of larvæ collected under each segment. According to these figures, the codling-moth larvæ, with one exception, preferred the northern exposure of the tree trunk.

TABLE LXXIX.—*Experiments with black and white bands for the codling moth, Grand Junction, Colo., 1916.*

Tree No.	Color of band section and location on tree trunk.	Number of larvæ collected beneath band sections.															Total number of larvæ.	
		July 8.	July 11.	July 14.	July 17.	July 20.	July 23.	July 26.	July 29.	Aug. 1.	Aug. 4.	Aug. 7.	Aug. 10.	Aug. 13.	Aug. 16.	Aug. 19.	Black band section.	White band section.
1	Black, N. E.	4	3	9	18	20	36	22	14	7	12	6	6	6	2	3	168	.....
	White, S. E.	0	2	0	0	0	2	4	1	0	3	0	0	0	0	0	.....	12
	Black, S. W.	1	2	6	14	16	29	10	6	4	4	2	0	2	2	4	102	.....
	White, N. W.	0	0	0	0	1	2	0	0	1	0	1	0	0	1	0	.....	6
2	White, N. E.	1	1	1	1	3	2	1	0	0	0	1	0	1	0	0	.....	12
	Black, S. E.	3	5	4	12	12	18	16	5	7	10	4	1	4	2	2	105	.....
	White, S. W.	0	0	1	0	0	1	1	1	0	1	1	0	0	0	0	.....	6
	Black, N. W.	6	9	12	14	19	14	15	7	4	6	2	7	5	7	3	130	.....
3	Black, N. E.	2	3	5	6	7	12	8	2	6	3	10	4	5	5	7	85	.....
	White, S. E.	0	0	0	0	1	3	3	1	0	0	0	0	2	0	1	.....	11
	Black, S. W.	3	0	6	1	13	4	4	3	4	3	3	2	3	4	3	56	.....
	White, N. W.	1	0	2	2	3	1	1	1	1	0	0	2	4	5	4	.....	27
4	White, N. E.	2	2	0	0	1	0	0	0	0	1	1	0	1	1	1	.....	10
	Black, S. E.	0	1	6	5	2	9	5	1	4	4	2	3	6	1	7	56	.....
	White, S. W.	1	0	0	0	2	1	1	0	0	2	4	2	3	5	0	.....	21
	Black, N. W.	10	12	10	7	21	15	10	11	14	7	7	9	2	2	7	144	.....
5	Black, N. E.	5	7	7	2	3	15	7	8	5	8	6	6	1	2	0	82	.....
	White, S. E.	1	1	0	0	0	1	2	0	1	4	0	0	1	1	1	.....	13
	Black, S. W.	0	2	2	1	7	3	7	3	3	0	3	2	1	1	4	39	.....
	White, N. W.	0	0	2	0	1	3	0	0	0	1	0	1	3	0	1	.....	12
6	White, N. E.	0	0	2	0	4	2	5	0	2	3	6	0	1	0	0	.....	25
	Black, S. E.	5	3	2	5	12	9	6	4	2	5	0	1	1	1	1	57	.....
	White, S. W.	0	0	0	0	0	1	3	2	0	0	1	0	0	0	1	.....	8
	Black, N. W.	21	11	20	12	27	26	25	5	7	15	4	5	4	3	2	187	.....
7	Black, N. E.	3	1	7	5	8	10	11	8	17	4	6	13	4	9	3	109	.....
	White, S. E.	1	0	1	0	0	0	0	2	1	1	1	0	3	1	0	.....	11
	Black, S. W.	0	0	4	2	6	5	3	2	2	4	1	1	4	4	2	40	.....
	White, N. W.	1	1	0	0	1	5	2	0	1	5	4	0	3	4	0	.....	27
8	White, N. E.	0	0	1	0	0	0	0	1	0	1	0	0	0	1	2	.....	6
	Black, S. E.	3	2	10	5	10	10	9	4	8	3	0	1	2	3	0	70	.....
	White, S. W.	1	0	0	0	0	1	1	2	0	1	0	0	3	1	4	.....	14
	Black, N. W.	6	11	21	11	20	21	27	4	7	9	8	3	6	13	4	171	.....
9	Black, N. E.	3	3	11	9	20	24	15	14	14	7	9	15	7	7	8	166	.....
	White, S. E.	0	0	0	2	1	6	4	0	3	3	7	6	4	4	1	.....	41
	Black, S. W.	0	2	15	12	13	25	19	8	2	3	2	9	5	7	4	126	.....
	White, N. W.	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	.....	3
10	White, N. E.	0	0	1	1	1	0	2	1	0	0	0	0	2	0	0	.....	8
	Black, S. E.	8	3	3	10	13	3	6	3	2	1	1	2	0	3	1	59	.....
	White, S. W.	0	0	0	1	0	0	1	0	0	0	0	0	0	0	4	.....	6
	Black, N. W.	10	9	11	16	13	17	19	5	3	4	7	6	2	5	4	131	.....
	Total larvæ	102	97	182	174	281	337	275	129	132	139	110	107	101	107	89	2,083	279

TABLE LXXX.—*Experiments with black and white bands for the codling moth, Grand Junction, Colo., 1916; summary of Table LXXIX.*

Color of band section and location on tree trunk.	Total number of larvæ collected.	Per cent of total number of larvæ.	Color of band section and location on tree trunk.	Total number of larvæ collected.	Per cent of total number of larvæ.
Black, N. E.	610	25.83	White, N. E.	61	2.58
Black, S. E.	347	14.69	White, S. E.	88	3.72
Black, S. W.	363	15.37	White, S. W.	55	2.33
Black, N. W.	763	32.30	White, N. W.	75	3.18
Total	2,083	88.19	Total	279	11.81

This experiment merely indicates that the codling-moth larva prefers a dark cocooning place. It should not be inferred that light-colored bands are of no value, since it is entirely possible that if the codling-moth larva has no better place to cocoon, it will be content to spin beneath bands of a light color. In orchard practice, burlap-

cloth bands, folded to two or three thicknesses, are very satisfactory for banding purposes.

PERCENTAGE OF TRANSFORMING AND WINTERING LARVÆ.

Season of 1915.—By reference to Table LXXXI it will be seen that 432 larvæ, or 47.52 per cent, of the first-brood larvæ that were reared in the insectary, transformed in 1915 to form the second brood; the remainder, 477, or 52.48 per cent, wintered. Out of 1,858 larvæ of the second brood, 20, or 1.08 per cent, transformed to form a third brood and the remainder, 1,838 larvæ, or 98.92 per cent, wintered. As previously mentioned, in the Grand Valley none of the third-brood larvæ transform until the spring of the next year.

TABLE LXXXI.—*Percentage of codling moth larvæ wintering, Grand Junction, Colo., 1915.*

Brood.	Number of larvæ—			Per cent transforming in 1915.	Per cent wintering.
	Leaving fruit.	Transforming in 1915.	Wintering.		
First	909	432	477	47.52	52.48
Second	1,858	20	1,838	1.08	98.92

Season of 1916.—The percentage of transforming and wintering larvæ of the first, second, and third broods reared in the insectary is given in Table LXXXII. As shown therein, 766 larvæ, or 74.15 per cent, of the first brood transformed; 267 larvæ, or 25.85 per cent, wintered. With the second brood, 170 larvæ, or 6.71 per cent, transformed and 2,362 larvæ, or 93.29 per cent, wintered. There were 328 third-brood larvæ, all of which wintered.

TABLE LXXXII.—*Percentage of codling moth larvæ wintering, Grand Junction, Colo., 1916.*

Brood.	Number of larvæ—			Per cent transforming in 1916.	Per cent wintering.
	Leaving fruit.	Transforming in 1916.	Wintering.		
First	1,033	766	267	74.15	25.85
Second	2,532	170	2,362	6.71	93.29
Third	328	0	328	0.00	100.00

LASPEYRESIA POMONELLA (L.) VAR. SIMPSONII (BUSCK).

During the course of the codling-moth studies, the light buff colored variety of the codling moth known as *Laspeyresia pomonella* (L.) var. *simpsonii* (Busck) was bred from material collected in the field.

REVIEW OF SEASONAL-HISTORY STUDIES OF THE CODLING MOTH IN 1915 AND 1916.

A generalized review of the seasonal-history studies of the codling moth is given graphically in figures 17 and 36 for the seasons of 1915 and 1916 respectively. The curves represent approximately the beginning, ending, and crest of activity of the more important biological stages of the insect.

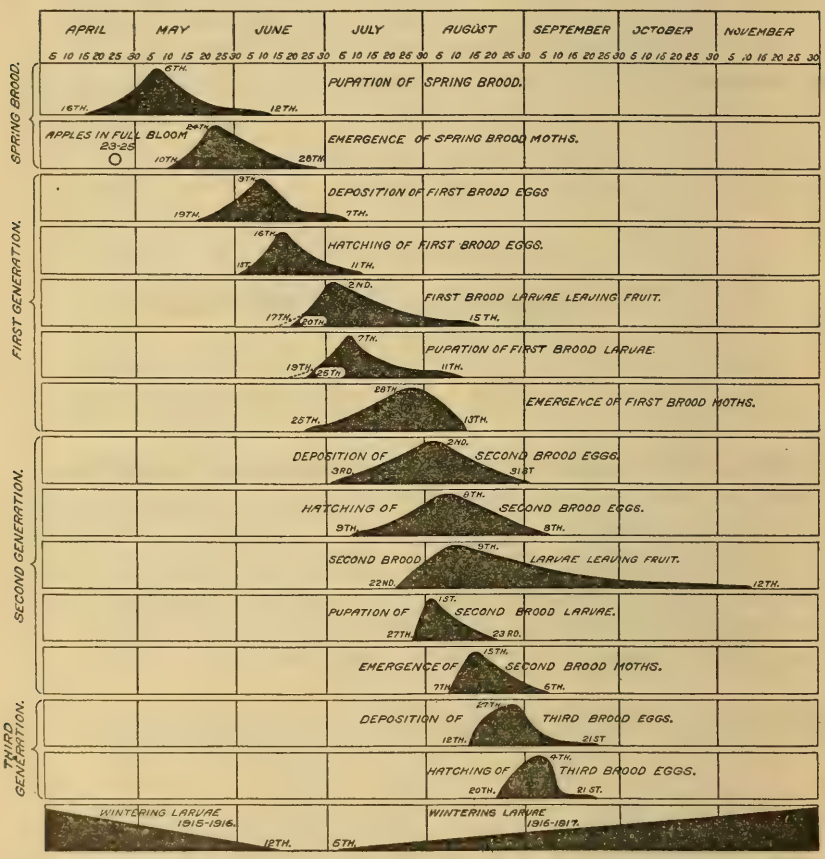


FIG. 36.—Diagram of life history of the codling moth in the Grand Valley of Colorado, 1916.

Pupation of spring brood.—In 1915 pupation commenced April 14, reached its maximum May 12, and ended June 8; in 1916 the earliest pupation took place April 16, was at its height May 6, and ceased June 12.

Emergence of spring-brood moths.—The first moth of the spring brood (1915) emerged May 12, the maximum emergence occurred May 24, and the last moth of this brood issued June 29. In 1916 the first spring-brood moth appeared May 10, the maximum emergence took place May 24, and the last moth issued June 28.

Deposition of first-brood eggs.—The spring-brood moths just referred to were employed in the oviposition studies. The earliest deposition of eggs of the first brood in 1915 occurred May 15, the greatest number of eggs was deposited on June 10, while the last egg was laid July 8. In the following year, the first eggs were deposited May 19, the crest of deposition was reached June 9, and the oviposition period ended July 7.

Hatching of first-brood eggs.—Hatching of first-brood eggs began in 1915 on May 27, and the eggs were hatching in largest numbers June 17. The last of the eggs hatched July 13. Hatching of first-brood eggs the next year commenced June 1, and on June 16 the eggs were hatching in maximum numbers, while the last of the eggs hatched on July 11.

First-brood larvæ leaving the fruit.—The time of larvæ leaving the fruit refers only to the insectary-reared individuals. In 1915 the first of these larvæ left the fruit June 21, on July 20 the largest number of larvæ made their exit from the apples, and on August 10 the last first-brood larva completed its feeding. According to the observations in the field, the first larvæ were collected in the Edwards orchard June 22 and in the Hamilton orchard June 28. In 1916 the first of the insectary-reared larvæ left the fruit June 20, the largest number left the fruit on July 2, and the last larva of this brood left the fruit August 15. But in the field the larvæ left the fruit at least three days earlier as shown by collections made in the Edwards and Hamilton orchards on June 17.

Pupation of first-brood larvæ.—The time of pupation of the first-brood insectary-reared larvæ in 1915 was as follows: First pupation June 27, maximum pupation July 6, last pupation August 4; in 1916 the first pupation took place June 25, the maximum pupation occurred July 7, and the last larva transformed on August 11.

Emergence of first-brood moths.—The time of emergence of first-brood moths as indicated in the diagrams refers to the moths that transformed from the field-collected larvæ. In 1915 the first moths of this brood (Hamilton orchard material) issued July 10, the maximum emergence occurred August 9, and the theoretical limit of emergence was August 19. In the following year all of the moths from the transforming larvæ collected in the Hamilton and Edwards orchards were used for oviposition purposes. The first of these moths issued June 25, the maximum emergence occurred July 28, and the theoretical limit of emergence was August 13.

Deposition of second-brood eggs.—Eggs of the second brood were first deposited in 1915 on July 12, on August 14 they were laid in maximum numbers, and on September 15 the last eggs were deposited. In 1916 the earliest deposition occurred July 3, the maxi-

mum deposition on August 2, and the deposition period ended August 31.

Hatching of second-brood eggs.—Eggs of the second brood (1915) commenced hatching July 19 and were hatching in maximum numbers August 21. The last eggs of this brood hatched September 24. In the following year the first eggs hatched July 9, and the largest number August 8. The hatching of this brood of eggs ceased September 8.

Second-brood larvæ leaving the fruit.—The data for these curves were taken from insectary-reared larvæ, and as shown in the graph the first larvæ left the fruit in 1915 on August 5. The larvæ left the fruit in largest numbers September 1, while the last larva of this brood completed its feeding period November 11. In 1916 the first larva emerged from the fruit July 22, on August 9 they left the fruit in maximum numbers, and the last larva of this brood made its exit from the fruit on November 12.

Pupation of second-brood larvæ.—Larvæ of the second brood (1915) began to pupate August 12. The last transformation took place October 2. In the succeeding year the pupation was as follows: First July 27, maximum August 1, last August 23.

Emergence of second-brood moths.—According to the insectary-reared material of 1915, the moths of the second brood commenced to issue August 23. The emergence ended October 14. During the season of 1916 the emergence period extended from August 7 to September 6, with the maximum of emergence occurring August 14.

Deposition of third-brood eggs.—The eggs of the third brood deposited in 1915 failed to hatch. The first egg was laid September 16, the last September 23. In 1916, however, fertile eggs were deposited, the oviposition period extending from August 12 to September 21 with the maximum deposition August 27.

Hatching of third-brood eggs.—None of the third-brood eggs from insectary-reared material hatched in 1915. In the following year the hatching period commenced August 20 and ended September 21. On September 4 the third-brood eggs hatched in greatest numbers.

Wintering larvæ.—The last of the wintering larvæ of the season of 1914 pupated June 8, 1915. The first larva taken in the field during the season of 1915 to pass the winter successfully and transform the following year to the adult stage was collected July 11 in the Edwards orchard. In 1916 the last wintering individual pupated June 12. Since no observations of the time of emergence of moths were taken in 1917, it is impossible to state just when the first wintering larvæ appeared in 1916. The part of the graph referring to the wintering larvæ of 1915–16 should be considered as an approximate estimate only.

SUMMARY.

The life-history studies recorded herein were made in the Grand Valley of Colorado during the seasons of 1915 and 1916.

The climate of the Grand Valley is comparatively dry and warm during the summer season, and is very favorable to the development of the codling moth.

According to the data secured in these studies, there are two complete generations and a partial third generation of the codling moth in the Grand Valley.

Length of the pupal stage of the spring brood.—In 1915 the length of the pupal stage of the spring brood averaged 27.58 days, the maximum was 34 days, and the minimum 15. In 1916 the average was 26.80 days, the maximum 36, and the minimum 13.

Oviposition by moths of the spring brood.—In 1915 the average number of days before oviposition was 6.19, the maximum 19, and the minimum 2; the average number of days for the period of oviposition was 13.82, the maximum 33, and the minimum 1; the average number of days from the date of emergence to the date of last oviposition was 19.14, the maximum 37, and the minimum 5. In 1916 the average number of days before oviposition was 6.07, the maximum 13, and the minimum 2; the average number of days for the period of oviposition was 13.38, the maximum 32, and the minimum 1; the average number of days from the date of emergence to the last oviposition was 18.46, the maximum 34, and the minimum 7.

Number of eggs per female moth of the spring brood.—According to the oviposition studies of the spring-brood moths of 1915, the average number of eggs per female moth was 12.59; in 1916, 11.34 eggs.

Length of life of moths of the spring brood.—In 1915 the average length of life of the male moths was 14.59 days and of the female moths 15.86 days; the maximum length of life of the male moths was 36 days and of the female moths 39 days; the minimum length of life of the male moths was 1 day and of the female moths 1 day. In 1916 the average length of life of the male moths was 14.67 days and of the female moths 15.73 days; the maximum length of life of the male moths was 35 days and of the female moths 39 days; the minimum length of life of the male moths was 1 day and of the female moths 1 day.

THE FIRST GENERATION.

Embryological changes and length of the incubation period of first-brood eggs.—The embryological changes in the eggs of the first brood and the length of the incubation period were as follows: In 1915 the average number of days from the date of egg deposition

to the time of the appearance of the red ring was 2.70, the maximum 9, and the minimum 1; the average number of days from the date of deposition to the black-spot stage was 6.62, the maximum 13, and the minimum 4; the average incubation period was 9.14 days, the maximum 15, and the minimum 6. In 1916 the average number of days from the date of deposition to the appearance of the red ring was 2.62, the maximum 10, and the minimum 1; the average appearance of the black spot from the time of egg deposition was 6.68 days, the maximum 11, and the minimum 5; the average incubation period was 7.32 days, the maximum 14, and the minimum 6.

Length of feeding period of the first-brood larvæ, stock-jar method.—During the season of 1915, the length of the feeding period averaged 21.64 days, the maximum was 35, and the minimum 12. In the following year the average length of the feeding period was 20.19 days, the maximum 42, and the minimum 14.

Length of feeding period of the first-brood larvæ, bagged-fruit method.—The records in 1915 give an average feeding period of 22.77 days, a maximum of 35, and a minimum of 15. In 1916 the average feeding period was 21.10 days, the maximum 29, and the minimum 17.

Length of cocooning period of larvæ of the first brood.—As shown by the observations in 1915, the average cocooning period was 6.70 days, the maximum 28, and the minimum 1. In the following season the average cocooning period was 5.53 days, the maximum 30, and the minimum 2.

Length of pupal stage of the first brood.—The average length of the pupal stage, first brood, in 1915 was 11.44 days, the maximum 31, and the minimum 6; in the succeeding year the average length was 11.23 days, the maximum 19, and the minimum 6.

Oviposition by moths of the first brood.—As shown by the studies in 1915, the average number of days before oviposition was 2.07, the maximum 5, and the minimum 1; the average number of days from the first to the last oviposition was 16.78, the maximum 25, and the minimum 7; the average number of days from date of emergence to last oviposition was 17.85, the maximum 26, and the minimum 10. The summarized data for 1916 are as follows: The average number of days from the date of emergence to the first oviposition was 2.21, the maximum 5, and the minimum 1; the average number of days from the first to the last oviposition was 12.69, the maximum 20, and the minimum 1; the average number of days from the time of emergence to the last oviposition was 13.63, the maximum 20, and the minimum 5.

Number of eggs per female moth of the first brood.—The moths of the first brood of 1915 deposited 46.73 eggs per female moth. In the following year the female moths deposited an average of 43.98 eggs.

Length of life of moths of the first brood.—In 1915 the average length of life of the male moths was 11.86 days, the maximum 41, and the minimum 1; the average life of the female moths was 12.68 days, the maximum 35, and minimum 1. In 1916 the summarized figures give 13.12 and 12.20 days as the average length of life of the male and female moths respectively. The maximum life of the male moths was 38 days and of the female 26 days; the minimum length of life of both the male and female moths was 1 day.

Life cycle of the first generation.—The average life cycle as obtained by rearing individuals from the egg to the adult stage, stock-jar feeding method, in 1915 was 49.30 days, the maximum 72, and the minimum 38. According to the bagged-fruit feeding method, the average life cycle was 49.18 days, the maximum 74, and the minimum 36. To obtain the complete life-cycle add 2.07 days, which was the average time from the emergence of the moths to the deposition of the first egg. In 1916 the average life cycle, stock-jar feeding method, was 44.89 days, the maximum 77, and minimum 36; and the average complete life cycle, obtained by adding 2.21 days to the life cycle, was 47.10 days. The average life cycle, bagged-fruit feeding method, was 46.37 days, the maximum 66, and minimum 38. The average complete life cycle was 48.58 days.

THE SECOND GENERATION

Embryological changes and length of the incubation period of second-brood eggs.—In 1915 the average number of days from the deposition of the egg to the appearance of the red ring was 1.85, the maximum 4, and the minimum 1; the average time for the appearance of the black spot was 5.54 days, the maximum 8, and minimum 3; the average incubation period was 7.22 days, the maximum 11, and minimum 6. In the next year the average appearance of the red-ring stage was 2.06 days after egg deposition, the maximum 3, and minimum 1. The average appearance of the black spot was 5.80 days, the maximum 7, and minimum 5. The length of the incubation period averaged 6.93 days, the maximum 10, and minimum 6.

Length of feeding period of second-brood larvæ.—The average length of the feeding period in 1915 was 28.69 days, maximum 67, and the minimum 15. In 1916 the average length of the feeding period was 28.61 days, the maximum 70, and the minimum 14.

Length of cocooning period of larvæ of second brood.—In 1915 the average length of the cocooning period was 9.35 days, the maximum 31, and minimum 3. In the following year the average number of days for the construction of the cocoon was 4.80, the maximum 14, and minimum 2.

Length of pupal stage of second brood.—The average length of the pupal stage of the pupæ of the second brood in 1915 was 15.62 days, the maximum 31, and the minimum 11. In 1916 the average length of the pupal stage was 13.51 days, the maximum 16, and the minimum 11.

Oviposition by moths of the second brood.—No oviposition data were obtained in 1915 owing to the fact that the eggs deposited by the moths of the second brood failed to hatch. In 1916 fertile eggs were deposited, but since moths emerging on different dates were confined in the same cages no oviposition data were obtained.

Number of eggs per female moth of the second brood.—In 1915 no fertile eggs were deposited, but in the following year the average number of eggs per female moth was 45.58.

Length of life of moths of the second brood.—The moths of the second brood of the seasons of 1915 and 1916 were not confined in separate cages according to their time of emergence. For this reason no data were obtained.

Life cycle of the second generation.—The life cycle of the second generation in 1915, as determined by rearing, was as follows: Average length of incubation period 6.12 days, average larval feeding period 20.49 days, average cocooning period 8.56 days, average pupal period 15.62 days, and average life cycle 50.81 days. In 1916 the records show that the average length of the incubation period was 6.01 days, the average larval feeding period 18.08 days, the average cocooning period 4.78 days, the average pupal period 13.52 days, and the average life cycle 42.40 days.

THE THIRD GENERATION.

Embryological changes and length of the incubation period of third-brood eggs.—In 1916 the average number of days from the date of deposition to the appearance of the red ring was 2.49, the maximum 5, and the minimum 2; the average number of days from the date of deposition to the appearance of the black spot was 6.36, the maximum 9, and the minimum 6; the average incubation period was 7.77 days, the maximum 11, and the minimum 7.

Length of feeding period of third-brood larvæ.—The average larval feeding period of the third-brood larvæ in 1916 was 37.55 days, the maximum 68, and the minimum 20.

PERCENTAGE OF TRANSFORMING LARVÆ.

Percentage of transforming larvæ of the first brood.—In 1915 47.52 per cent of the first-brood larvæ transformed, while in the following season 74.15 per cent pupated.

Percentage of transforming larvæ of the second brood.—In 1915 1.08 per cent of the second-brood larvæ transformed. In 1916 6.71 per cent of these larvæ transformed.

Percentage of transforming larvæ, band material.—In 1915 the percentage of larvæ collected in the field in connection with the band studies that transformed to the adult stage was 45.37, and in 1916 40.88.

MISCELLANEOUS.

Natural enemies.—The following predators were recorded: A small beetle, *Tenebroides corticalis* Melsh., and a spider, *Coriarachne versicolor* Keys.

The following parasites were observed: *Trichogramma minutum* Riley, *Dibrachys clisiocampae* Fitch, and *Arthrolytus apatelae* Ashmead. The predacious and parasitic enemies play a very unimportant rôle in checking the codling moth in the Grand Valley.

The emergence of moths from fruit cellars is later than that in the field. The period of emergence in fruit cellars, however, is shorter than that which obtains under field conditions.

The majority of the moths of the spring and first broods emerge during the latter part of the morning and early part of the afternoon.

The codling moth is believed to be a nonmigratory species except for short local flights. The moths have, however, strength to fly in a continuous flight, unaided by the wind, for a distance of at least one-half mile.

The codling moth is most active in depositing her eggs late in the afternoon to early in the evening, the activity being greatest just about dusk.

The fecundity of the codling moth in the Grand Valley is high. Three female moths of the first brood deposited in confinement over 300 eggs each, the highest total deposition by one moth being 316 eggs, 115 being the largest number deposited in one day by a single female.

The codling moth larva normally cuts its way through the eggshell and emerges head first. Occasionally it will protrude the anal end first, but in this case it is sometimes unable to extricate itself.

An examination of a pear orchard devoid of fruit revealed the fact that codling moth larvæ will sometimes burrow into the new growth, resulting in the browning of the foliage.

The codling moth larva prefers to spin up under dark-colored bands.

The buff-colored variety of the codling moth known as *Laspeyresia pomonella* (L.) var. *simpsonii* (Busck) was reared in the Grand Valley.

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UNITED STATES DEPARTMENT OF AGRICULTURE

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WILLIAM B. GREELEY, Forester

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BLACK WALNUT: ITS GROWTH AND MANAGEMENT.

By F. S. Baker, *Forest Examiner.*

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INTRODUCTION.

The importance of black walnut (*Juglans nigra*, Linn.) was impressed upon the whole Nation by the efforts made during the war to secure black-walnut wood for gunstocks and airplane propellers. The supply, which has never been large in comparison with the supply of other woods, was greatly depleted to satisfy these war-time demands. The demand for black walnut has continued strong since the close of the war period, and comparatively high prices have been maintained. Even during peace times there is sure to be a constant though moderate call for walnut and at higher prices than are obtained for most other North American woods.

In order that the supply of black walnut may not be inadequate for manufacturing needs in the event of another war, there should be a reserve of growing timber. Whatever the Government may accomplish in this direction on its own lands, every farm within the range of walnut growth on which trees of this species are found is potentially a part of such a reserve. Obviously, black walnut is a very valuable element of any timberland or farm wood lot in which it grows. Great importance, therefore, attaches to the questions of available supply, growth, and management of black walnut, and of the financial possibilities of growing it for the timber market. It is the purpose of this bulletin to present such information as is available on these subjects.

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DISTRIBUTION OF WALNUT.

BOTANICAL RANGE.

That there is a considerable quantity of walnut still left in the country is due to the immense area on which the species grows and not to the presence of large supplies in any one region. The botanical

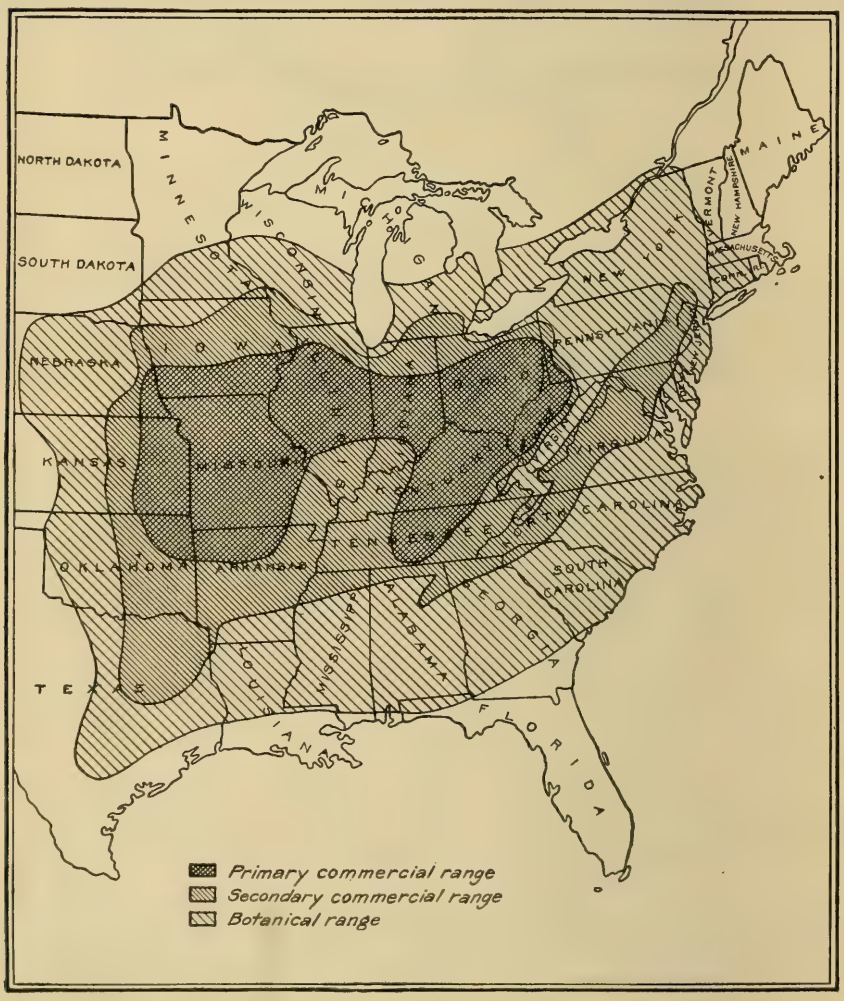

FIG. 1.—The range of black walnut.

range, as shown in figure 1, is from southern New England and Ontario to Minnesota, South Dakota, and Nebraska, south into Texas and east to Georgia, reaching the Atlantic coast line in South Carolina. Planting has introduced walnut into every State in the Union,

although usually in the sections outside its range occasional shade trees only are found.

COMMERCIAL RANGE.

The commercial range is also very wide, extending in places almost to the limits of the botanical range, the value of walnut being sufficient to warrant the cutting and shipment of amounts as small as part of the range from as far as Kerrville, Uvalde, and New Braunpoint.

During the war the commercial range was probably wider than ever before except toward the southwest, where the quality of the wood is unsuitable for lumber. Some of the outlying shipping points in the northern part of the range were Crofton, Nebr. (some of the logs coming from near Yankton, S. Dak.), Garden City, Minn., and Ferryville and Madison, Wis. Michigan shipments have come from as far as 80 miles north of the Indiana line and from an island in the Detroit River. In the northeastern part of the range, the region about Geneseo, N. Y., and Long Island mark the outermost points at which commercial amounts have been found. In the southeastern portion logs have come from the region of Columbia, S. C., from a mill operated for a time at Columbus, Ga., and from another at Montgomery, Ala., although only a part of the logs were obtained in the locality. West of the Mississippi, logs have come from as far south as Shreveport, La., and along the Red River; and in the southwestern part of the range from as far as Kerrville, Uvalde, and New Braunfels, Tex. In the western region logs came from as far as Thomas, Okla.; Great Bend, on the Arkansas River in Kansas; and Stockton, on the Solomon. No records of shipments have come from very far west in Nebraska, Crete being about the limit.

The best natural development of walnut is to be found probably in the Ohio River Basin, in the southern Appalachians, or in Arkansas. The best groves placed on the market in late years were at Danville, Ill., and Excelsior Springs, Mo.; but this was because the old original stands had been preserved through the personal desires of the owners rather than because of any exceptional growing conditions. That exceptionally large trees are not limited to any particular region is shown by the widely distant points from which large logs have been obtained for various expositions. A 12-foot log, 52 inches in diameter, from Jackson County, N. C., was exhibited at the Centennial Exposition, Philadelphia, in 1876; and a 16-foot log, 77 inches in diameter, from Mormon Creek, Bates County, Mo., at the World's Fair, Chicago, in 1893. A 20-foot log, 52 inches in diameter, from the Osage Reservation of the Indian Territory, was secured for exhibition at the Paris Exposition, in 1900.

INFLUENCE OF SOIL AND CLIMATE UPON DISTRIBUTION.

Throughout its wide range the local distribution of walnut is controlled by climatic and soil factors, which affect not only its abundance and commercial value but also the other species with which it characteristically associates in the forest. In general, walnut is found on rich, moist but well-drained soils. It is more dependent upon these conditions than are many of its associates, and a relatively slight inferiority in any of these respects may be reflected either in a scarcity of walnut or in slow and scrubby growth. Its dependence upon good soil is more marked, however, in regions in the western part of its range, which have a relatively scant precipitation, than it is in well-watered regions like those in the southern Appalachians. In the latter situations it makes a better development on rocky and shallow, though by no means sterile, soils than could be expected elsewhere, compensation for the deficiency in soil qualities being made by the abundance of the summer rains.

West of the Wabash River and in the Mississippi Valley below Illinois walnut of good development is almost invariably on rich bottom lands. An exception to this is its occurrence in the Boston Mountains of Arkansas, where because of the heavier precipitation it is found on flat mountain tops and benches. It is, however, by no means a stream-bank tree in the sense in which sycamore, river birch, and willow are. These species, though frequently growing near by, are rarely seen in intimate mixture with walnut except in the moister places in the eastern part of its range. This is probably because the soil for walnut must be not only moist but well drained and aerated as well—a fact which, no doubt, also explains in large measure the lack of walnut in such places as the Mississippi bottom lands, which are subject to protracted flooding. The deficiency in soil aeration may also be responsible for the exceedingly slow growth and virtual failure of certain plantations on rich but exceedingly compact bottom-land soils, heavily sodded and never thoroughly broken.

LOCAL FORMS OF GROWTH AND ASSOCIATED SPECIES.

Walnut is found in three characteristic situations—as scattered field and fence-corner trees, as scattered trees in hardwood stands, or as pure stands, usually on the edge of the hardwood forest.

In fields, particularly in the Ohio River basin, it sometimes represents a remnant of the original stand, left because of its value when the land was cleared for agriculture. The fence-corner trees have come up because the uncultivated soil attracted squirrels to bury the nuts there and because in such situations the trees were protected from injury. Ever since the days of the great popularity of walnut furniture there has been a tendency among farmers to conserve this

tree more than associated species, partly because of a vague notion that it had exceptional value and partly, no doubt, on account of the yield of nuts.

As scattered trees in the hardwood forest, black walnut is found throughout the eastern part of the country, and here it is not restricted to the bottom lands. It usually forms a very small proportion of the total stand, especially in the Southeastern States, where the forest is composed of a great variety of species. In the Ohio River basin it is found in most of the open wood lots, where constant culling is reducing the stand and grazing is preventing all reproduction. In the repeated cuttings that have gone on in these groves for the last 30 years, walnut trees too small to be merchantable were often left to grow, in the hope that the earlier demand for walnut would be renewed. West of the Mississippi walnut becomes a more prominent component of the river-bottom forests, and in parts of eastern Kansas and Nebraska it is distinctly the dominant, sometimes practically the only, member of the stand.

Pure stands of walnut are somewhat common in much of the Ohio River basin, where they are typically found adjoining stands of mixed hardwoods and extending as open groves into pasture lands. These groves are valuable sources of supply, for the trees are fairly uniform in size and are much less expensive to market than are scattered trees. Pure stands of walnut are also frequent in certain localities in the western part of its range, although the stands as a rule contain an admixture of elm and hackberry at least, and frequently a number of other species. Pure stands are rarely dense enough to keep out grass, but the sod is usually not normally thick in these places.

The wide range of walnut involves its association with a vast number of other species, from basswood and hemlock in the northern part of its range to holly and shortleaf pine in the southern part. In the Ohio-Indiana region it is found most frequently with ash, oaks, beech, maple, hickory, elm, cherry, and Kentucky coffeetree. South of the Ohio River the most prominent difference is the association of red cedar and walnut, which is especially characteristic in Kentucky and middle Tennessee. In the Appalachian Mountain walnut is widely scattered, but reaches its best development on bottom lands and coves below 4,000 feet in elevation. Its associates are very numerous in this region, red oak, white oak, yellow poplar, and chestnut being the chief. In Illinois its more common associates in the river-bottom hardwood types are oaks, white elm, and ash. Toward northern Illinois and Wisconsin basswood and sugar maple become more important, but do not extend far over into Iowa. West of the Mississippi white elm, oaks, hackberry, and to a lesser extent hickory

(*Hicoria minima*) are typically found with walnut. Cottonwood is exceedingly common along streams, but it is more frequently an inhabitant of the bars and sandy banks of the large rivers than of the deep, rich soils of the smaller stream bottoms where the walnut is found. In Kansas, elm, hackberry, and walnut are constantly found together in stands of varying composition as far south as the Arkansas River, where a flora more characteristically southern, containing various oaks, makes up much of the valley forest. Wherever Kentucky coffeetree, is found walnut is almost invariably present, and this tree may be accepted as a trustworthy indicator of a site suitable for black walnut.

SUPPLY.

The supply of black walnut has been reduced in much the same way as that of all our hardwoods since the settlement of this country. Certain factors, however, notably the value of both the tree itself and the soil it thrives on, have together induced a comparatively rapid decrease in the amount of black walnut, which never was really abundant. Therefore we now have less of this than of any other commercially important wood, with the exception of cherry and, possibly, black locust.

ESTIMATED STAND BY STATES.

To make a definite statement in regard to walnut resources at this time would be quite impossible, because the trees are so widely scattered and so seldom found in any large quantity that authentic figures for even limited regions are difficult to obtain. The fact that such large amounts came to light during the war has led to over-optimistic estimates in many quarters, as a sort of reaction from the unduly low estimates that were popular for many years before the war. The best information at hand gives the present stand for the country as 821 million feet, distributed among 28 States, as shown in Table 1. Of this amount probably 50 per cent is inaccessible to the manufacturers, half of this on account of the unwillingness of owners to sell at any price and half on account of the excessive cost of getting the timber out from the remote valleys of the southern Appalachians and Ozarks. Even at war prices hauls of over 20 miles to railroads were very rare, and all timber farther removed is virtually inaccessible. The remaining 50 per cent consists of material generally smaller and of poorer quality than existed in the older stands, and in the East it is very largely in the form of scattered field and fence-corner trees and of shade trees about the farm.

TABLE 1.—*Estimated amount of standing walnut, in millions of board feet, by States. (Trees 12 inches in diameter and over, breast high.)*[1]

Middle Atlantic States	30
New York	2
New Jersey	2
Pennsylvania	26
South Atlantic States	64
Delaware	1
Maryland	5
Virginia	29
North Carolina	14
South Carolina	7
Georgia	8
North Central States	211
Ohio	63
Southern Michigan	15
Indiana	44
Southern Wisconsin	10
Illinois	79
South Central States	187
West Virginia	60
Kentucky	67
Tennessee	60
Prairie States	215
Minnesota	3
Iowa	60
Missouri	107
Nebraska	18
Kansas	27
Southern States	114
Arkansas	46
Oklahoma	18
Texas	37
Louisiana	3
Mississippi	4
Alabama	6
Total	821

IMPORTANCE OF WALNUT IN THE DIFFERENT STATES.

NEW ENGLAND STATES.

The stand of walnut in the New England States, except in western Connecticut, is confined to scattered planted trees.

[1] It is not claimed that these quantities are accurate. They are very general approximations based upon the best available evidence, and should be held subject to correction on the basis of future timber estimates.

MIDDLE ATLANTIC STATES.

New York.—Although the entire State of New York lies within the botanical range of black walnut, there are only a few places where the species exists plentifully. Sullivan and Orange Counties, in the southeastern part of the State, contain commercial amounts; but on the west bank of the Hudson, above Newburgh, and from the Hudson eastward as far as, but not including, Long Island, it is very scattered. In the Genessee Valley, especially in Livingston County, walnut is found in amounts sufficiently large to warrant commercial exploitation if the demands were similar to those of war time.

New Jersey.—Walnut is plentiful in the western part of New Jersey, especially in Sussex, Warren, Hunterdon, and Cumberland Counties, being, of course, most abundant and of the best quality on the better soils. On the sandy soils farther east its growth is slower and its quality inferior, although large trees are frequently found.

Pennsylvania.—In the northern and central parts of Pennsylvania walnut is very rare. West and southwest of this region of scarcity lies a belt in which walnut is somewhat common on the good soils of the valleys, but is lacking in the mountains. The southwestern and southeastern parts of the State contain stands of walnut scattered very generally throughout the hardwood forests, particularly in the larger valleys.

SOUTH ATLANTIC STATES.

Maryland.—Valuable stands are found only in the western part of Maryland. The infertile red clays prevailing farther east and the sands of the coast belt are not favorable to a good development of walnut.

Delaware.—Only the northernmost portion of Delaware contains native walnut of high quality.

Virginia.—The Shenandoah Valley remains the best walnut region of Virginia, although the abundance of walnut there has been greatly reduced. Commercial quantities are still to be found throughout the whole length of the valley, as well as in the coves and valleys on both sides of the mountains. On the east slope of the Blue Ridge a considerable amount of walnut is found in small, fertile mountain valleys. To a lesser extent it grows on the slopes of these small valleys but is of inferior quality. In the Piedmont region the river valleys contain considerable walnut, the Potomac and Rappahannock basins contain the most, and the York and James somewhat less. South of this region walnut is scarce, and is found in carload lots only in the broadest of the bottom lands, the poor red soils of the uplands being unfavorable to its development. On the coastal plain of Virginia walnut is rare.

FIG. 1.—NATURAL GROVE OF BLACK WALNUT IN DECATUR COUNTY, IND.

FIG. 2.—OPEN WOODLOT IN INDIANA, IN WHICH BLACK WALNUT IS CHARACTERISTICALLY GROWING IN MIXTURE WITH OAKS AND OTHER HARDWOODS. SOME WALNUT TREES HAVE RECENTLY BEEN CUT.

FIG. 1.—GROVE OF BLACK WALNUT IN INDIANA, FRINGING MIXED HARDWOOD STAND AT RIGHT.

FIG. 2.—WHITE OAK COMING IN UNDER BLACK WALNUT THAT FIRST INVADED THE PRAIRIE SOD.

IN THE APPALACHIAN MOUNTAINS BLACK WALNUT OCCURS IN MIXTURE WITH CHESTNUT, YELLOW POPLAR, RED OAKS, AND HICKORIES. VIEW IN SWAIN COUNTY, N. C.

North Carolina.—The coves and valleys of the mountain region of western North Carolina up to an elevation of 4,000 feet are the most favorable sites in the State for walnut. For many years these forests have been subjected to selective logging, carried on at greater and greater distances from shipping points, and the walnut has been removed along with other valuable species. This process culminated in the close search for walnut during the war. As a result, stands containing much walnut of merchantable size and quality can now rarely be found in the western part of the State, except in remote sections distant from railroads or in places otherwise difficult of access. In the Piedmont region it is found commonly as far east as a line relatively parallel to the mountains and passing through Statesville, and in this region perhaps the largest amounts in the State exist at the present time. Still farther east walnut is occasionally found on better bottom lands, but in many large areas it is entirely lacking, although hedgerow and roadside trees which have been protected are not infrequent.

South Carolina.—As a whole, walnut is not commercially important in South Carolina, being found in quantity only in the one tier of counties next to the mountains. Throughout the Piedmont region, as far as Columbia, it is usually found only as scattered trees on rich soils, but in some localities it is more abundant.

Georgia.—Walnut is of importance only in the Appalachian Valley region of northeast Georgia and the Blue Ridge region to the east, where a few counties contain 40 per cent of the total stand. Toward the southeast the proportion of native walnut decreases, and along the two or three rows of counties back from the coast nothing but planted walnut or protected roadside trees is reported. Nowhere is there now sufficient walnut to give the section any commercial importance, and the scattered walnut of the Piedmont region is hardly more considerable.

NORTH CENTRAL STATES.

Ohio.—Ohio is one of the famous old producers, and, in spite of a somewhat dense population and large agricultural area, there are still large amounts of walnut to be found, especially in the broken east central part of the State, where it flourishes in fields and in mixed hardwood stands and seems to be reproducing in a satisfactory way. It is common but less plentiful over the remainder of the State.

Southern Michigan.—Although a famous hardwood State, Michigan is too far north to have very much walnut. This wood has been shipped from as far north as the fourth tier of counties above the Indiana line, a distance of 80 miles. Toward the southwest, on account of the sandy soils, it is only occasionally found, but over

most of the two southern tiers of counties it is plentiful as a field tree. The quality is excellent to its northern commercial limit.

Indiana.—The whole State of Indiana has a high reputation for black walnut, but at present the species is irregularly distributed, a condition that is explained by the differences in the soil and by the settling and clearing of the land for agriculture. The northwest part of the State never has been to any great extent a walnut section, the poorly drained lands of the Kankakee River and the sandy stretches about the south end of Lake Michigan being unfavorable to this species. In the northeastern part of the State and in a region south of the Wabash River, embracing all but the lower third of the State, soils are excellent, and walnut is everywhere seen in fields, along roads, in wood lots, and especially west of Indianapolis, in pure groves fringing mixed hardwood stands. The south third of the State is more rolling and broken, and walnut is largely confined to valleys and protected slopes. The soils in some places are sterile clays underlaid by hardpan or rock, and are unfavorable for walnut, which is, therefore, scarce in these localities. In the region as a whole, however, walnut is of commercial importance. The forests of the Wabash Valley below Vincennes and of the Ohio Valley below Evansville tend toward types more characteristically southern, and walnut becomes more rare.

Southern Wisconsin.—Walnut exists in commercial quantities in southwest Wisconsin below a line running from La Crosse to Baraboo and Madison. It is nowhere very evident, but rich pockets of pure stands are found in out-of-the-way valleys. The trees usually grow as pure grooves in grassy hollows or scattered singly among the other species in the better class of hardwood stands. Walnut grows much farther north in Wisconsin, but is sparsely distributed, usually as widely scattered individual trees.

Illinois.—Most of the walnut in Illinois is found north of a line from St. Louis to Terre Haute, and is generally limited to the bottom lands and moist flats. Walnut is an important element of the hardwood stands in this region and is particularly abundant in the central part of the State. On the poorly drained and sandy soils in northeastern Illinois there is less walnut, and in the hardwood forests of southern Illinois it forms a smaller proportion of the stand than in the bottom-land forests farther north.

SOUTH CENTRAL STATES.

West Virginia.—The walnut in West Virginia is largely confined to the northwestern half of the State. The elevation of the southeastern half of the State is in general too high and the soil is too shallow and poor for walnut, although there are many valleys which

contain a considerable amount of merchantable walnut, as well as much small growth. In the region of the Great Kanawha and New Rivers the walnut has been almost entirely removed. In the extreme southwestern part of the State there are scattered stands. Though walnut grows to good size in West Virginia, it is not so large, in general, as in Ohio or Indiana, and it is also more defective.

Kentucky.—Kentucky is a heavy producer of walnut and still contains large quantities in spite of long-continued cutting. The bluegrass region of central Kentucky is the main source of supply on account of the ease with which most of the timber may be obtained and because of its general distribution on nearly every farm and wood lot. The largest amounts, however, are in the mountains of eastern Kentucky, but these supplies have hitherto been inaccessible, even at high war prices, on account of the long hauls over inferior roads and the small amounts available in any one place. In extreme western Kentucky the principal forest is the more characteristically southern type of bottom-land hardwoods in which walnut is an insignificant member.

Tennessee.—Tennessee is divided into three walnut-producing districts—east, middle, and west Tennessee—each containing different topographical and forest types. East Tennessee is mountainous and contains a great deal of walnut scattered as field trees in the agricultural lands of the valleys and appearing quite generally in wood lots and in the hardwood type, where it makes excellent development. On pine lands it is more rarely seen and is of inferior form. In the mountains it is found up to 4,000 feet in elevation, usually in coves with rich, deep soil, along with yellow poplar and white and red oaks. In the rolling country of middle Tennessee it is a common tree, although its development is inferior to that in east Tennessee. In the aggregate there is probably more walnut in this section than in either of the other divisions of the State. It is found in limestone soils, even where outcrops indicate a shallow soil, and it frequently associates with red cedar. In the hollows and valleys of the limestone region it reaches excellent proportions. West Tennessee tends to the alluvial-bottom type and contains only a scattering of walnut.

PRAIRIE STATES.

Southern Minnesota.—There is very little walnut in Minnesota, although some has been cut in the two southern tiers of counties, where conditions are similar to those of northern Iowa.

Iowa.—Iowa is one of the most important sources of walnut, particularly in the southern and southeastern parts. The loess soils of this State are deep and rich, and the broad river bottoms present large areas of well-watered soils in which walnut thrives. Planted on the uplands, walnut usually grows slowly, and its development

is unsatisfactory. Along the Mississippi and Missouri Rivers it is found in draws leading down to the streams, where branches have been cut through the bluffs. These draws contain a considerable quantity of walnut which may be regarded as here marking the most northerly limit of growth in commercial amounts.

Missouri.—Missouri ranks first in the amount of its standing walnut. The distribution of the walnut is somewhat uneven on account of the diverse topographic, soil, and climatic conditions. North of the Missouri River these conditions resemble those of Iowa, and the river bottoms and moist draws support relatively large stands of walnut in mixture with oaks, elm, hackberry, and, sometimes, along larger streams, cottonwood. The quality is good, although the trees do not, as a rule, reach a very large size. South of the Missouri River, in the western part of the State not included in the Ozark Hills, the conditions are more like those of eastern Kansas, and the proportion of walnut to other hardwoods is even greater. The third division of Missouri—the Ozark region—occupies most of the State south of the Osage River. Here walnut is found everywhere in the bottom-land forests, though rarely in pure groves. On the slopes and uplands it is absent. In the aggregate there is a large amount still standing in the Ozark region, and in more remote districts there is doubtless much excellent stuff, for even at the height of the war demand walnut was seldom cut farther than 20 miles from the railroads. There are probably 2,200 square miles of this more remote section from which only the best veneer logs have been removed. Under present market and labor conditions this region is virtually inaccessible. The fourth region is the heavily wooded southeast portion of the State from St. Louis southward, comprising the Mississippi bottom lands. Walnut is found here, scattered through the bottom-land hardwood forest, but in quantities too small for general commercial exploitation.

Nebraska.—In the southeast corner of the State there is a great deal of walnut along stream bottoms, but north of the Platte it is less abundant, and is found in commercial amounts chiefly near the Missouri River in draws where creeks break through the bluffs.

Kansas.—In eastern Kansas walnut is a very prominent constituent of the bottom-land forests for long distances, frequently composing 30 per cent of the stand. It is nearly always associated with elm and is usually second in importance to this tree, which extends to drier lands than the walnut. Hackberry is very frequent, and bur oak, white oak, and many other species may also be found in smaller amounts. Occasionally the stand will be pure walnut over areas of 5 to 20 acres, but mixed stands are the rule. Walnut is sometimes found on the northern slopes of the river bluffs among oaks and elms, usually where the slope is gentle and the soil is deep, especially near

springs or seeps. Small streams usually have the most favorable bottom lands; such rivers as the Kansas and Arkansas deposit too much sand along their bottoms.

SOUTHERN STATES.

Arkansas.—Walnut is widely distributed in Arkansas, usually in the deep rich soils of the stream bottoms; but its growth in large quantities is mostly confined to the northern part of the State. In the northwestern region, known as the Boston Mountains, the physiographic and climatic conditions are such that walnut ceases to be a river-bottom tree and appears upon the level terraces and mountain tops, which alternate with steep escarpments. Here the soil is rich and deep, of limestone and sandstone origin, and bears a blue-grass sod in most places. The rainfall is greater than in other regions west of the Mississippi River and conditions more closely resemble those of central Kentucky and Tennessee. In much of Arkansas the walnut is difficult of access, as the stands are far from railroads and hauling is expensive.

Oklahoma.—Walnut is of considerable importance as a bottom-land tree in Oklahoma. In the western part of the State it is scattering or only locally abundant; but in the eastern part, the old Indian Territory, it is still very common, although a great deal was recently cut, and the remaining timber is therefore mostly small. This region contained the last of the virgin walnut. The wood is considered inferior to walnut grown farther north and is little sought for milling.

Texas.—Conditions are widely variable in Texas, and the development of walnut is correspondingly irregular. The species is found over the whole eastern part of the State, though it is nowhere very abundant at the present time, the region having been worked heavily for export during the last 20 years. On the lower stretches of the rivers the prevailing forest is of the southern hardwood bottom-land type, consisting mainly of gums, oaks, and cypress and containing little walnut; but toward central Texas the southern species drop out one by one, and walnut becomes increasingly important until the western limits of its range are reached, where it associates with Mexican walnut (*Juglans rupestris*). In the black-soil region the wood is dark and uniform, producing veneers of a deep brown color with even a purple or dark-greenish shade. Toward the limestone region of the Edwards Plateau, where the conditions of growth are severe, the wood is light in color, streaked with darker shades, and sometimes so variable and so dark lined as to pass for genuine Circassian walnut. Valuable burls also come from this region. Texas walnut is defective in general and at present is not often cut for milling.

Louisiana, Mississippi, and Alabama.—In Louisiana walnut is not found in the pine type and is rare in the alluvial bottom-land type—the two types which comprise by much the greater part of the forest area; but commercial amounts are sometimes found in the Red River Valley, in the northwestern corner of the State. In Mississippi walnut is widely scattered through the extensive alluvial bottom hardwood type, but is so scarce that shipments of logs from any part of the State are rare. Alabama has never figured as a walnut-producing State, most of this species being found in the northeastern part, in the valleys of the Tennessee and Coosa Rivers.

FUTURE SUPPLIES.

The future supply of walnut can not well be inferred from any statement of the present stand of merchantable timber, because in such a statement immature trees are not considered. An estimate of the average annual yield is much more expressive of what may be expected in the future. Previous to the war the average annual cut probably ran between 40 and 50 million board feet a year, and those most familiar with the situation believed that this represented fairly well the cut that might be sustained continuously. This was borne out by the discovery during the war that the country actually had much more merchantable walnut than anybody supposed, although the increase was due in part to closer utilization and the release, as an act of patriotism, of supplies not usually on the commercial market. The war cut heavily into the growing stock, however, and the yield for some years will be reduced. Nevertheless, if the amount of young growth is in normal proportion to the older trees there is no reason why the old sustained yield of 40 to 50 million board feet should not be resumed.

An estimate of the amount of immature timber is even more difficult to make than an estimate of the merchantable stuff. Among those informed, the opinion is common that in most of its range there is an abundance of young walnut down to 6 or 8 inches in diameter. There is an astonishing lack of reproduction below this size, except in the upper Ohio and eastern region. The trees now rated as unmerchantable—and this is particularly true in the western part—are, as a rule, not thrifty young trees, but older growth that has been suppressed and stunted, though still capable of recovery and of development into saw timber. From this source there is a fair assurance of a moderate supply of black walnut for, perhaps, 30 years, comparable in amount to the walnut cut during the 20 years before the war. If a great war should occur during the next 30 years much difficulty would be experienced in securing desirable amounts of walnut. It is too late now to provide for any material increase in

the supply during that period, although the situation may be somewhat ameliorated by the careful management and conservation of remaining stands. At the end of this period the remaining supply will begin to decrease unless active steps are now taken to secure an adequate replacement by extensive planting or by forest management to secure natural regeneration. The upper Ohio Valley and Appalachian region is too limited to maintain a very large output. There is absolutely no need, however, of our sacrificing a national asset like black walnut, which may be perpetuated if the proper action is taken.

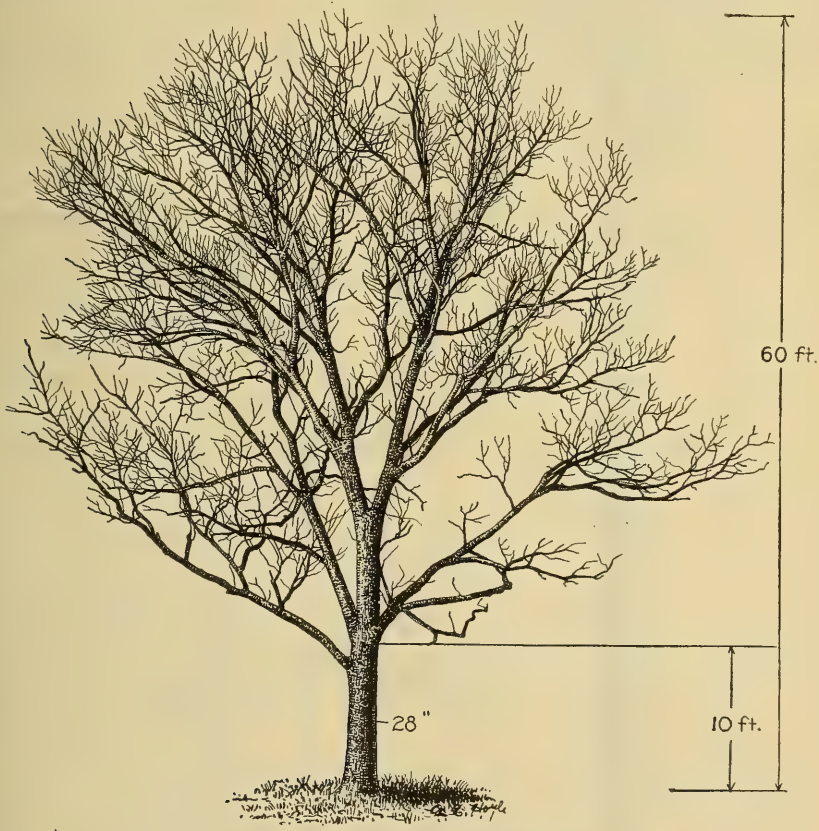

FIG. 2.—Open-grown black walnut tree.

DESCRIPTION OF THE TREE.

SIZE AND FORM.

Black walnut is naturally a large tree, and, if it were given time and a favorable site, it would grow to magnificent proportions. At present, however, it is a rare thing to see trees over 30 inches in diameter, breast high, and these are usually open grown with broad-spreading crowns and short trunks. Logs as large as 77 inches at the

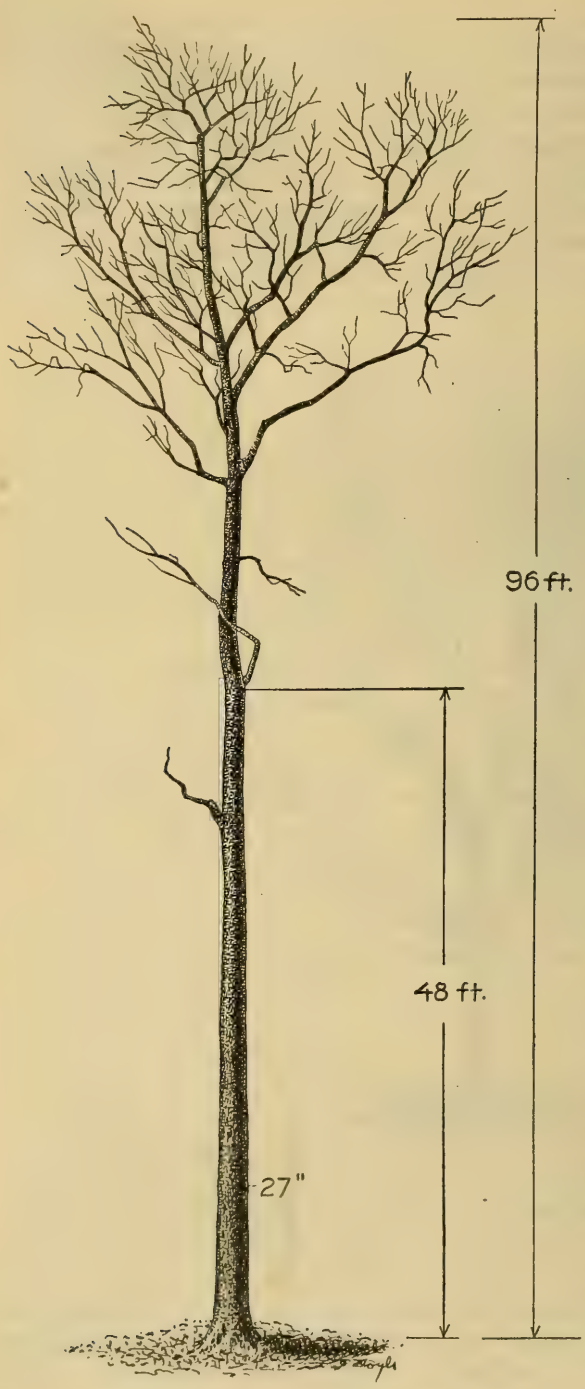

FIG. 3.—Forest-grown black walnut tree.

small end have been cut, and heights of 125 to 150 feet are on record, although to-day trees 100 feet tall are rare. The average tree that is cut at present contains about 15 feet of merchantable length.

When it has grown in the open, black walnut has the appearance of an orchard tree, with a short, clear bole and a round, spreading crown, which in summer exhibits a mass of beautiful foliage. In the winter the coarse branching habit and the large, dark twigs usually make it easy to identify the tree even at considerable distances, although young and abnormal trees may sometimes be mistaken for ash or hickory. In the forest a typical black-walnut tree presents a tall, clean bole of little taper up to the lowest branches. At this point the identity of the main trunk is frequently lost, and a few large limbs spread out to form a rounded crown at the level

of the forest canopy. The greater merchantable length, the more slender and more gradually tapering stems, and the smaller, more restricted crowns of forest-grown trees are in conspicuous contrast to the short, thick, rapidly tapering trunks and full crown of trees grown in the open. Of two neighboring trees measured in Indiana—one a field and the other a forest tree—the former, because of rapid taper and low branches, had only about 15 feet of merchantable length, but the latter had nearly 30 feet. Forest-grown trees near Fort Wayne, which measured from 30 to 35 inches in diameter, breast high, had from 64 to 72 feet of merchantable length.

It is very characteristic of walnut, both in the open and in the forest, for the main trunk to break up within a few feet of the lowest limbs into a number of large branches, no one of which appears to be the leader.

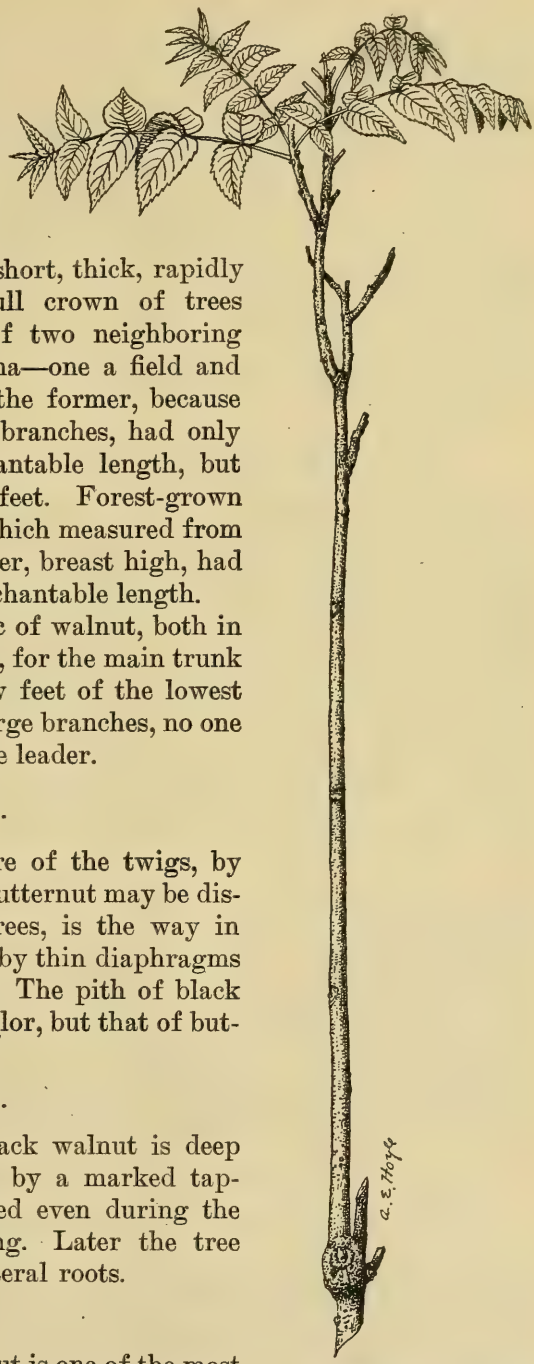

FIG. 4.—Black walnut seedling from a brushy site, at beginning of third year of growth.

TWIGS.

A characteristic feature of the twigs, by which black walnut and butternut may be distinguished from other trees, is the way in which the pith is divided by thin diaphragms into spaces or chambers. The pith of black walnut is of a pale buff color, but that of butternut is dark brown.

ROOTS.

The root system of black walnut is deep seated and characterized by a marked taproot. This is well defined even during the first year of the seedling. Later the tree throws out prominent lateral roots.

BARK.

The bark of black walnut is one of the most variable features of the tree, the differences being caused largely by different rates of

growth. The bark of a rapidly growing walnut tree is thin and reticulated in some places almost as much as the bark of ash; but, as a rule, the ridges and furrows are much larger and less regular, and the reticulation is not apparent. The color of the bark from inside to outside is always dark, being almost black when it is wet after a rain. On slow-growing old trees the bark becomes several inches thick and is broken up into irregular blocks by transverse cracks. This is especially true toward the southwestern limits of the walnut range in Texas, and there the color becomes lighter, being a reddish brown in some localities. The darker bark, as well as the greater straightness of bole and better general symmetry, are, however, usually sufficient when leaves and fruit are absent to distinguish walnut from butternut, or white walnut, as it is called in some sections.

LEAVES, FLOWERS, AND NUTS.

The leaves are pinnate, from 1 foot long on forest-grown trees to 2 feet on vigorous trees in the open, with from 15 to 23 leaflets, smooth and light shiny green above, paler and somewhat hairy below. The leaves closely resemble those of butternut and, to a less extent, those of ailanthus. In the midsummer the tree is very ornamental, but because the leaves are put out late the winter appearance continues for a relatively long time.

Flowers are borne at the same time the leaves begin to develop, the staminate or male flowers in catkins 3 to 5 inches long, and the pistillate or female flowers in inconspicuous clusters of two to five greenish flowers, on the ends of the branches. Only one or two of these pistillate flowers develop into nuts. The mature nuts are round to pear-shaped and 1½ to 2 inches in diameter outside the greenish fleshy husk that incloses them. The nut proper is nearly spherical, with many ridges roughening the surface. The value of the nuts as articles of sale is variable. Although in general the nuts have meats moderate in size and difficult to remove from the shell, the nuts from certain trees are exceptional both as to size and cracking qualities. The trees that provide these exceptional nuts are of value in developing special horticultural varieties.

SILVICAL CHARACTERISTICS.

SOIL AND MOISTURE REQUIREMENTS.

The requirement of black walnut for fertile, moist, but well-drained soils has already been discussed. This requirement should be kept in mind in selecting sites for the planting of walnut. In addition, because of the deep root system of walnut the subsoil underlying the planting site should be of a porous texture to a corresponding depth. A dry atmosphere does not seem greatly to

affect the growth of the tree, provided the soil conditions are suitable, for the development is good in the irrigated plantations that are scattered through the arid West, and the natural range of walnut extends in Texas into a region of relatively light rainfall. Its dependence upon good soil is more marked, however, in regions that have a relatively scant precipitation than it is in well-watered regions.

TOLERANCE OF SHADE.

Walnut is decidedly intolerant of shade, although its ability to endure shade varies with site and soil conditions and the age of the tree. During the first few years of its life it will bear considerable side shading, as is shown in occasional instances in which walnut was planted between rows of corn and grown successfully in combination with corn for two or three years. In mixed hardwood forests, where there is a lack of light, walnut reproduction is practically never found. It is found on the edges of the forest, along roadways and streams, and in other places where the continuity of the forest cover is broken. In the East, at least, it can come up successfully through brushy tangles of sassafras, sumac, rose, and raspberry bushes, and in between clumps of shrubby willows. In plantations the interlocking of the crowns soon causes a decided reduction of diameter growth; and, after the tree has attained a height of 30 to 40 feet, height growth is no longer stimulated by crowding, the effect of which is, rather, to cut down all increment. Suppressed trees in these conditions become stag-headed and put out water sprouts all the way up and down the trunk.

REPRODUCTION.

Black walnut reproduces both by seed and by sprout, the former means being very much the more common. The nut crops are usually generous and the percentage of fertility is high. Transportation of the seed to any distance, however, is practically dependent upon squirrels, and the greater part of the walnut reproduction is undoubtedly from nuts that are buried by squirrels in open grasslands adjoining forests. Started under these conditions, the seedlings receive the abundant light needed for their vigorous development. It is doubtful, in fact, whether the seedlings can successfully establish themselves from nuts that are left lying on the surface of the ground or are only lightly covered with fallen leaves. Of the nuts buried in the forest only a small proportion produces successful trees; most of the seedlings are eventually suppressed by the overhead shade unless they are fortunately located under some break in the forest canopy. This characteristic of walnut reproduction makes it appear likely that in many of the mixed stands containing walnut the walnut was the first to start, originating from nuts buried by squirrels in

open meadows and prairies, and that the associated species came in later beneath the walnut, after the latter had established forest conditions. The agency of squirrels in the establishment of walnut is probably responsible also for the frequency of practically even-aged groves of walnut. Of some even-aged stands, which started within the memory of living man, it is known that the small fields and hillsides they now occupy were seeded by squirrels in a single year. It is quite likely that this is the usual origin of even-aged stands that have sprung up without human action. Whether this is due to exceptionally heavy seed crops or to bad winters that killed off the squirrels before the nuts were dug up and eaten, or to short winters that did not force the squirrels to consume all their hoard, or to a combination of such circumstances, can not now be told.

Reproduction is remarkably rare in the greater part of the range of black walnut under conditions as they now prevail. Practically all walnut stands are grazed by cattle, that destroy the young seedlings, or, still worse, by hogs that eat the nuts. Consequently, no reproduction of walnut or anything else is taking place, and the stands are becoming grovelike, with open grassy floors. Even where grazing is excluded, however, walnut reproduction is not generally seen. This is difficult of explanation, but possibly it is linked with the effect of the settlement of the country on the number of squirrels and their habits.

In western Indiana profuse reproduction is occasionally found along the fence rows around fields containing old walnut trees, as well as scatteringly on open southern slopes of draws leading down to the Wabash River on both the Indiana and the Illinois sides. In some localities in Missouri young trees are characteristically scattered on open southern slopes near hollows that contain mature walnut. The growth on these open slopes, however, will be subnormal and the trees will be poor.

Conditions are much better farther eastward, and in such regions as southwestern and southeastern Pennsylvania, parts of West Virginia, northern Virginia, Maryland, northern Delaware, and western New Jersey reproduction is locally profuse. It is usually found along stream courses passing through agricultural lands, pastures, or woodlands, although by no means exclusively limited to such sites. Along roadsides, the edges of wood lots, fence rows, and, in fact, in almost any place where there is protection and sufficient light young walnut is likely to be found. In all this region the reproduction of walnut is rendered more certain than farther west, on account of the fact that the woodlands are not generally grazed here, while grazing is the rule in the Ohio Valley and westward. Even in this region of maximum reproduction, however, trees above 6 inches in diameter are seen much more frequently than seedlings.

Sprout reproduction occurs irregularly from stumps of small and moderate-sized trees cut, apparently, at any season of the year. The sprouts are usually numerous and come from the side of the stump somewhat above the root collar. During the first few years the sprouts usually grow tall, weak, and crooked, resembling those of cottonwood, especially if they are not in full light. The first season's growth probably continues until frost, which kills back the tops of the sprouts for as much as a foot. Unless there is plently of light, all the sprouts usually die in a few years. In the open, one or two or even three sprouts may persist and grow into fair-size trees. The original stump rots away, however, weakening the base of the sprout and infecting it with red butt rot. Sprout reproduction rarely produces a good tree of saw-log size. Certainly it is not to be considered seriously as a means of regenerating a stand.

DISEASES AND INJURIES.

FUNGI.

Black walnut is moderately free from tree diseases and is as resistant to injury as any of its associates. Red butt rot is found in a small percentage of trees, mostly old trees of northern growth, although it is very bad in parts of central Kentucky. As a rule the rot extends only a short distance up the tree, and "butting off" the lower 3 or 4 feet of a hollow tree will usually remove most of this defect. The "doty" zone that surrounds the advanced decomposition at the center is generally narrow; it is frequently possible, in fact, to saw boards within an inch of an open hollow before any discoloration appears.

A white top rot is found, limited almost entirely to southern logs, particularly from Oklahoma and Texas. Its presence is indicated by punky knots and occasionally by conks on the upper trunk. This rot extends a greater distance up and down the trunk than the red butt rot and is a much greater detriment to the logs, especially if they are to be used for sawing into lumber. A large log with a defective center might be made to furnish a large amount of first-class veneer, but could not to advantage be sawed into lumber.

INSECTS.

A tent caterpillar disfigures the foliage of many roadside trees and reduces the rate of their growth. It is reported, however, to be rare in forest-grown trees and groves, walnut being worst affected when it grows near cherry or apple trees. In ornamental trees the nests should be promptly burned. Except for this caterpillar, walnut is very free from insect pests.

GROWTH OF INDIVIDUAL TREES.

Walnut may be classed among the more rapid growing hardwoods. The fertility of the soil on which black walnut is usually found greatly facilitates the growth of the tree. The poorer the site, the slower are all phases of growth, in height, in diameter, and consequently in volume. Growth is also affected by the shade from adjacent trees, and this accounts for the characteristic differences in form. The rate of diameter growth, on soils of equal quality, depends normally upon the amount of foliage, and hence is slower in the small-crowned trees of the forest than in spreading-crowned open-grown trees. When the trees are suppressed by the shade of taller trees, diameter growth is greatly decreased.

HEIGHT GROWTH.

Table 2 gives an idea of the average height growth of black walnut in comparatively open, pure stands in central Indiana and Ohio. It should be accepted as applicable only to "grove walnut":

TABLE 2.—*Height growth of walnut in comparatively open stands in central Indiana and Ohio.*

Age.	Height.	Age.	Height.	Age.	Height.
Years.	*Feet.*	*Years.*	*Feet.*	*Years.*	*Feet.*
10	13	60	72	110	84
20	35	70	75	120	85
30	53	80	78	130	86
40	62	90	81	140	87
50	68	100	82	150	88

DIAMETER GROWTH.

In the course of this study diameter-growth measurements were made on 128 trees located at 16 places in 6 States. While the number of trees thus scattered is too small to afford reliable data, the average measurements shown in Table 3 will give a general idea of the average rate of diameter growth, breast high, of walnut under neither the best nor the poorest conditions:

TABLE 3.—*Breast-high diameter growth of walnut, based on measurements of 128 trees widely scattered.*[1]

Age.	Diameter, breast high.	Age.	Diameter, breast high.	Age.	Diameter, breast high.
Years.	*Inches.*	*Years.*	*Inches.*	*Years.*	*Inches.*
10	1.2	60	18.3	110	26.0
20	5.0	70	20.6	120	26.9
30	8.8	80	22.2	130	27.8
40	12.5	90	23.8	140	28.5
50	15.7	100	25.0	150	29.2

[1] Distribution of measurements: Indiana, 37 trees from 5 localities; Ohio, 75 trees, 3 localities; Illinois, 5 trees, 1 locality; Virginia, 5 trees, 1 locality; New Jersey, 7 trees, 1 locality; Missouri, 3 trees, 1 locality.

A few selected measurements are given below as illustrating the rate of diameter growth under specific conditions. It should be noted that they do not afford a safe basis for the comparison of different regions, since local differences in soil and stand may affect the rate of growth even more than a wide geographical separation:

(1) Near Indianapolis, Ind.; illustrating the difference in diameter growth of four trees that grew in the open and three that grew in the forest. The two situations were about one-quarter of a mile apart and the soil in both cases was deep, dark loam. The stand containing the forest-grown trees was open and parklike, as a result of cutting operations in late years. The other species in the stand were white ash, white oak, white elm, beech, sugar maple, hackberry, Kentucky coffee tree, and hornbeam. (Table 4, No. 1.)

(2) Fayette County, Ohio; a similar comparison of diameter growth in open fields or groves (45 trees) with that (of 13 trees) in dense stands of mixed hardwoods. The growth both in the open and in the forest is less than in the preceding case, probably due, in part, to less favorable soil and moisture conditions. (Table 4, No. 2.)

(3) Near Indianapolis, Ind.; eight trees that grew on a southwestern slope on the southern edge of a mixed hardwood stand of ash, elm, and white oak. (Table 4, No. 3.)

(4) Near Indianapolis, Ind.; six trees in a pure walnut grove on a flat meadow adjoining a mixed hardwood stand of oak, elm, ash, and hackberry. This stand is now somewhat dense and diameter growth is probably relatively low in late years. (Table 4, No. 4.)

(5) Near Fort Wayne, Ind.; five trees in a virgin mixed hardwood stand composed of white oak, elm, yellow poplar, and ash, with a slight amount of black walnut, located on a flat, with deep, rich, loamy soil of potential agricultural value. These trees are probably typical of the growth of the older walnut stands cut 40 years ago. (Table 4, No. 5.)

(6) Near Deer Park, Boone County, Mo.; three trees from a grove on bottom lands. (Table 4, No. 6.)

(7) Eleven butt logs laid aside for veneering at Indianapolis; of unknown source, but probably from Indiana. These are very choice logs—round, clear, of rapid growth, and indicative of the average maximum growth in this region. (Table 4, No. 7.)

(8) Two butt logs from Marshall, Ind. (Table 4, No. 8.)

(9) Five butt logs from Farmersburg, Ind. (Table No. 4, No. 9.)

(10) Four butt logs from Carmel, Ind. (Table 4, No. 10.)

(11) Seven butt logs from Shreve, Ohio. (Table 4, No. 11.)

(12) Six butt logs from Mount Gilead, Ohio; apparently came from a wheat field. (Table 4, No. 12.)

(13) Five butt logs at Farmville, Va.; probably forest grown in mixed hardwood stand on rich bottom land. (Table 4, No. 13.)

(14) Seven stumps, New Jersey. (Table 4, No. 14.)

(15) Two stumps near Cameron, Mo.; in a mixed hardwood stand on a northern exposure considerably above the stream bottom. Stump diameter, 17 inches, age 59 years. False rings were numerous. This growth was a little below the average.

(16) Three stumps on the Kansas River bottom lands near Lawrence, Kans. Averaged 28 inches in diameter, stump height, at 63 years; a very rapid growth.

(17) Three butt logs at Kaw City, Okla. Averaged 30 inches in diameter on the butt end at 88 years, which is also above the average. The logs came from the bottom lands of a tributary of the Arkansas River.

(18) Six stumps at Valley Falls, Kans., in the bottom lands of Delaware Creek. Averaged 25 inches in diameter, stump height, at 64 years; also above the average rate of growth.

(19) Five stumps in northern Delaware. Averaged 25 inches in diameter, stump height, at 94 years.

(20) One hundred 20-inch logs taken at random in Missouri, Iowa, and Kansas. Averaged 83 years of age at the top end. Logs of this size measured in Indiana and Ohio were 81 years of age. These figures would apparently indicate that the rate of diameter growth of walnut is about the same in the river-bottom woodlands of the prairie States as it is farther east.

TABLE 4.—*Examples of diameter growth of black walnut based on age described under the corresponding numbers on page 23.*

No.	Grown in—	Age (years).														
		10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
		Diameter at breastheight (inches).														
1	Forest	0.2	1.4	3.6	6.5	12.1	16.1	19.5	21.4	.....	.....	.....	.....	.....	.....	.....
	Open	1.4	5.4	10.2	14.8	18.8	22.3	24.6	.....	.....	.....	.....	.....	.....	.....	.....
2	Forest	.6	3.1	5.4	8.0	10.8	12.9	15.2	17.2	19.1	20.8	22.4	.....	.....	.....	.....
	Open	.6	3.1	5.4	8.5	11.8	15.0	17.8	20.5	22.8	24.9	26.6	.....	.....	.....	.....
3	(1)	1.0	4.9	9.1	12.6	14.6	17.0	19.4	20.5	.....	.....	.....	.....	.....	.....	.....
4	(1)	1.7	7.0	12.6	16.1	18.8	20.6	22.0	23.3	23.5	.....	.....	.....	.....	.....	.....
5	(1)	1.4	4.4	7.4	10.7	13.5	15.8	18.0	19.6	21.4	23.3	24.3	25.6	26.8	28.0	29.3
6	(1)	1.4	5.3	8.1	10.8	13.5	16.6	19.6	.....	.....	.....	.....	.....	.....	.....	.....
7	(1)	2.4	6.4	10.7	15.0	18.3	21.4	24.0	26.3	28.0	.....	.....	.....	.....	.....	.....
8	(1)	4.1	10.2	15.0	18.3	20.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	(1)	.4	3.1	6.2	9.6	12.9	16.4	19.2	21.9	23.9	.....	.....	.....	.....	.....	.....
10	(1)	2.0	6.4	10.6	14.6	17.6	21.0	24.0	25.7	.....	.....	.....	.....	.....	.....	.....
11	(1)	.9	4.4	7.4	11.8	16.0	20.5	24.3	.....	.....	.....	.....	.....	.....	.....	.....
12	(1)	2.0	7.5	13.1	18.1	22.0	25.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	(1)	1.4	5.8	10.2	14.0	17.4	20.0	22.3	24.2	.....	.....	.....	.....	.....	.....	.....
14	(1)	.8	7.1	13.0	17.5	20.6	23.4	24.0	24.6	.....	.....	.....	.....	.....	.....	.....

[1] See description on p. 23.

VOLUME GROWTH.

As the growth of a tree in volume depends upon the rate of growth in both diameter and height, it is more variable than either. A statement of the increment in board feet to be expected at the end of any period will consequently have little bearing upon any particular stand. In order, however, to present a general idea of the average volume growth of individual trees, Table 5 has been prepared. It indicates fairly well the volume growth in groves in the Ohio Valley, but does not apply to single trees or rows grown in the open, to forest-grown trees, particularly in the eastern part of the range, or to trees in artificial plantations. It is less applicable to groves in regions east or west of the Ohio Valley.

It is evident from this table that walnut may be grown most advantageously, from the standpoint of greatest continuous volume production, on long rotations, for the reason that both the average annual growth and the current annual growth continue to increase up

to 150 years at least. The age to which individual walnut trees could be best grown, from the standpoint of greatest volume production, is probably limited not so much by an ultimate decrease in the rate of volume growth as by the setting in of butt rot. The average age at which logs are cut at the present time is 80 or 90 years—a period at which the tree is making rapid growth.

TABLE 5.—*Volume growth of black walnut.*

Age.	Volume.	Average annual growth.	Current annual growth.[1]
Years.	*Board feet.*	*Board feet.*	*Board feet.*
50	48	1.0	---
60	100	1.7	5.2
70	150	2.1	5.0
80	200	2.5	5.0
90	260	2.9	6.0
100	320	3.2	6.0
110	380	3.5	6.0
120	440	3.7	6.0
130	505	3.9	6.5
140	565	4.0	6.0
150	635	4.1	7.0

[1] Average annual growth for each decade.

RELATION BETWEEN RATE OF GROWTH IN DIAMETER AND THE FORMATION OF SAPWOOD.

The thickness of the sapwood depends very largely upon the rapidity of growth, the trees which have grown most rapidly having the widest sapwood. For this reason thrifty young trees are more likely to have wide sapwood than old trees. Local differences in site, however, frequently modify the tendency to vary with rapidity of growth. Trees from certain regions are notoriously sappy, but from other places the percentage of black heart is uniformly high. The relation of rapidity of growth to thickness of sapwood is shown in Table 6, which is based on 124 logs from widely scattered points. Of those trees in which the rate of growth was about the average the sapwood contained from 12 to 14 annual growth rings.

TABLE 6.—*Thickness of sapwood.*[1]

Growth last decade.	Thickness of sapwood.	Years in sapwood.	Growth last decade.	Thickness of sapwood.	Years in sapwood.	Growth last decade.	Thickness of sapwood.	Years in sapwood.
Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*	
0.2	0.3	25	0.9	1.2	14	1.5	1.9	13
.3	.4	20	1.0	1.4	14	1.6	2.0	13
.4	.7	18	1.1	1.5	14	1.7	2.1	12
.5	.8	16	1.2	1.6	13	1.8	2.2	12
.6	.9	15	1.3	1.7	13	1.9	2.4	12
.7	1.0	14	1.4	1.8	13	2.0	2.5	12
.8	1.1	14						

[1] Based on measurements of 124 logs.

The light-colored sapwood of black walnut used to be considered more of a defect than it is now. It is the present practice of most manufacturers to subject their lumber to a steaming process as soon as it comes from the saw. This steaming turns the sapwood to the same color as the heartwood and renders it equally salable. The sapwood of posts decays very much faster than the heartwood, and this renders the use of round walnut posts decidedly unsatisfactory.

GROWTH OF STANDS (YIELD PER ACRE).

It is difficult to estimate the yield on an acreage basis, of a species that characteristically grows so scattered as black walnut does. However, the yields of pure, open, grovelike stands are given here as examples of what may be expected of natural stands under the best conditions.

The first example is that of a walnut stand covering an area of 2.5 acres, located in Decatur County, Ind. The growth is scattered somewhat regularly over the whole area, except near the middle, where an area of perhaps one-quarter of an acre was cleared around a gas well. The stand is entirely of walnut, apparently even-aged and about 50 years old. The forest floor is covered by a bluegrass sod and is grazed by hogs and cattle. Naturally under these circumstances there is no reproduction. The slope is slightly to the north, where a small permanent stream bounds the grove. The soil is a deep, rich loam, similar to that of the cultivated fields adjoining. (See Table 7.)

TABLE 7.

Diameter breast high.	Number of trees per acre.	Estimated yield per acre.	Diameter breast high.	Number of trees per acre.	Estimated yield per acre.
Inches.		*Board feet.*	*Inches.*		*Board feet.*
Below 8	10.0	.....	20 to 22	6.0	960
8 to 10	.8	.....	22 to 24	2.4	552
10 to 12	1.6	.....	24 to 26	1.6	512
12 to 14	6.8	.....	26 to 28	1.2	534
14 to 16	8.4	336	28 to 30	.4	246
16 to 18	7.1	497			
18 to 20	9.3	1,023	Total per acre	55.6	4,660

The larger merchantable trees on this area, together with some very large, short, "fence-corner" trees on another part of the farm—a total of 68 trees estimated to contain 15,000 board feet—were sold for $102.50 a thousand board feet on the stump. The above estimate of 4,660 board feet in this grove is believed to be low; but if it is accepted as it stands it gives a value of $477.65 an acre after 50 years, or an annual income of $9.55 an acre. In making comparisons it is imperative to remember that this stumpage price was exceptionally high even in a period of vastly inflated war prices. Before the war $40 a thousand would have been high.

The second example is that of a small grove of 48-year-old walnut mixed with younger trees of other species, in Hendricks County, Ind. The grove occupies six-tenths of an acre and is in a pasture adjoining a mixed hardwood stand of shagbark and bitternut hickory, white oak, elm, sycamore, and an occasional black walnut. This grove apparently illustrates the invasion of meadowland by the forest, in the progress of which walnut was the leader, the associated species being mostly young trees which came in after the walnut was established. The stand is still too small to show a large yield in board feet. (See Table 8.)

TABLE 8.

Diameter breast high.	Number of trees per acre.		Walnut yield per acre.
	Walnut.	Other species.[1]	
Inches.			*Board feet.*
Below 8	5.2	15.5	----------
8 to 10	8.6	3.4	----------
10 to 12	6.9	1.7	----------
12 to 14	10.4	10.4	----------
14 to 16	8.6	----------	344
16 to 18	6.9	----------	483
18 to 20	1.7	----------	187
Total	48.3	31.0	1,014

[1] Elm, shagbark, white oak, bitternut, and hackberry, in the order of abundance.

Another stand of much the same form was found in Hendricks County, Ind., growing under similar conditions in a pastured area. Originally this stand fringed a mixed hardwood stand very similar to the previous example, but the timber has been largely removed. This walnut stand is not quite pure, but has a slight admixture of hickory, oak, and Kentucky coffeetree, along with seedlings of ash and Kentucky coffeetree. There is an excellent sod, and the area is grazed by cattle. The walnut stand occupies half an acre. The age of the stand is not known, but it is evident that it is still immature and will have a very much greater value in 20 or 30 years. (See Table 9.)

Another walnut grove in Jefferson County, Kans., shows that stands of this kind are by no means limited to the Ohio Valley. This stand, which is about 60 years old, and nearly even aged, is located on the bottom lands of Cedar Creek, on an area of about 15 acres, bounded on the south by Cedar Creek and on the north by corn land. This land is subject to overflow for a few days in exceptional years, but usually it is above high water. The soil is a deep, dark loam, which gives excellent corn yields in the adjoining fields. The stand has not been grazed, and there is a considerable amount of

undergrowth of young elm, hackberry, and *Crataegus*, but not of walnut.

TABLE 9.

Diameter breast high.	Number of trees per acre.		Yield per acre of walnut.
	Walnut.	Other species.[1]	
Inches.			*Board feet.*
Below 8	4	2	----------
8 to 10	6	----------	----------
10 to 12	12	2	----------
12 to 14	4	4	----------
14 to 16	2	2	80
16 to 18	8	----------	560
18 to 20	8	2	880
20 to 22	0	----------	----------
22 to 24	1	----------	230
24 to 26	----------	----------	----------
26 to 28	----------	----------	----------
28 to 30	----------	----------	----------
30 to 32	----------	2	----------
Total	45	14	1,750

[1] Shagbark hickory, Kentucky coffeetree, and white oak, in order of abundance. The two trees 30 to 32 inches in diameter were white oak.

Of the trees over 8 inches in diameter, breast high, the stand contains, on an average, 23 merchantable walnut trees to the acre, 38 unmerchantable walnuts, and 8 other trees (hackberry, burr oak, and Kentucky coffeetree). The merchantable trees average 2.45 logs to the tree, or 24.5 feet of merchantable length. The average log contains 55 board feet. Each tree, therefore, averages 135 board feet, and the merchantable stand to the acre is 3,275 board feet. These figures are based on 208 logs that had been cut and were actually scaled. This stand was too small to show maximum productivity, but it indicates what may actually be secured in 60 years in western river-bottom lands.

MEASURING LOGS AND ESTIMATING STANDING TIMBER.

MEASURING LOGS.

The Doyle rule (Table 10) is in general use for scaling walnut logs, and has been used in this bulletin in all computations involving board feet. This rule penalizes small logs very heavily, and does not at all represent the amount that can actually be sawed from them. With the present run of logs averaging 70 to 80 feet to the log, 1,000 feet scaled in the log by the Doyle rule will cut about 1,400 feet of lumber. In logs about 25 inches in diameter the Doyle scale represents closely the actual amount that can be cut in walnut of good quality.

ESTIMATING STANDING TIMBER.

Because of the high value, scattered occurrence, and variation in form, of black-walnut trees, estimates of their volume are now made, not by the "cruising" methods commonly practiced in the timber

TABLE 10.—*The Doyle log rule.*

Diameter in inches.	Length in feet.										
	6	7	8	9	10	11	12	13	14	15	16
	Board feet.										
6	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4
7	3.4	3.9	4.5	5.1	5.6	6.2	6.8	7.3	7.9	8.4	9
8	6	7	8	9	10	11	12	13	14	15	16
9	9	11	12	14	16	17	19	20	22	23	25
10	13	16	18	20	22	25	27	29	31	34	36
11	18	21	24	28	31	34	37	40	43	46	49
12	24	28	32	36	40	44	48	52	56	60	64
13	30	35	40	46	51	56	61	66	71	76	81
14	37	44	50	56	62	69	75	81	87	94	100
15	45	53	60	68	76	83	91	98	106	113	121
16	54	63	72	81	90	99	108	117	126	135	144
17	63	74	84	95	106	116	127	137	148	158	169
18	73	86	98	110	122	135	147	159	171	184	196
19	84	98	112	127	141	155	169	183	197	211	225
20	96	112	128	144	160	176	192	208	224	240	256
21	108	126	144	163	181	199	217	235	253	271	289
22	121	142	162	182	202	223	243	263	283	304	324
23	135	158	180	203	226	248	271	293	316	338	361
24	150	175	200	225	250	275	300	325	350	375	400
25	165	193	220	248	276	303	331	358	386	413	441
26	181	212	242	272	302	333	363	393	423	454	484
27	198	231	264	298	331	364	397	430	463	496	529
28	216	252	288	324	360	396	432	468	504	540	576
29	234	273	312	352	391	430	469	508	547	586	625
30	253	296	338	380	422	465	507	549	591	634	676
31	273	319	364	410	456	501	547	592	638	683	729
32	294	343	392	441	490	539	588	637	686	735	784
33	315	368	420	473	526	578	631	683	736	788	841
34	337	394	450	506	562	619	675	731	787	844	900
35	360	420	480	541	601	661	721	781	841	901	961
36	384	448	512	576	640	704	768	832	896	960	1,024
37	408	476	544	613	681	749	817	885	953	1,021	1,089
38	433	506	578	650	722	795	867	939	1,011	1,084	1,156
39	459	536	612	689	766	842	919	995	1,072	1,148	1,225
40	486	567	648	729	810	891	972	1,053	1,134	1,215	1,296

forests, in which all or many of the species are to be logged together, but by the separate examination of each merchantable tree. The usual practice is to estimate first the length and small-end diameter inside the bark of each log in the tree, and then to find the contents of the logs in board feet by the Doyle rule. To estimate closely the length and taper of the logs and their diameters inside the bark requires a practiced eye and a knowledge of bark characteristics, in order that the thickness may be gauged from appearances with relative accuracy. In most merchantable logs the bark averages from 1 to 1½ inches in thickness, as shown in Table 11.

TABLE 11.—*Thickness of bark, in inches, on logs of different diameters.*[1]

Diameter of log.	Bark thickness.	Diameter of log.	Bark thickness.	Diameter of log.	Bark thickness.
6	0.5	15	1.1	24	1.3
7	.5	16	1.2	25	1.4
8	.6	17	1.2	26	1.4
9	.7	18	1.3	27	1.4
10	.8	19	1.3	28	1.4
11	.9	20	1.3	29	1.4
12	1.0	21	1.3	30	1.4
13	1.0	22	1.3		
14	1.1	23	1.3		

[1] Based on 291 logs mostly from Ohio and Indiana.

In selling walnut on the stump the owner should accompany the buyer, who is usually an experienced walnut cruiser, and with him estimate the length and small diameter of each log that will be cut, keeping a detailed memorandum of the scale and the sizes agreed upon.

The average form and development of trees of different diameters at breastheight are shown in Table 12, which may be used as a rough volume table for average trees, particularly if they have been grown in groves or wood lots. The trees used as a basis grew in Ohio and Indiana, but the form is probably very much the same throughout the range of walnut, except where conditions are very unusual, as around the outer limits of the range, particularly toward the west and southwest.

TABLE 12.—*Form and volume of walnut trees of different diameters, breast high.*

Diameter breast high (inches).	Distance above ground (feet).									Total height (feet).	Merchantable length[2] (feet).	Volume[3] (board feet).
	1[1]	10	20	30	40	50	60	70	80			
	Diameter inside bark (inches).											
1	2.6	0.2	.....	.....	.....	.....	.....	.....	.....	11	.....	.....
2	3.5	1.0	.....	.....	.....	.....	.....	.....	.....	16	.....	.....
3	4.3	1.7	0.1	.....	.....	.....	.....	.....	.....	22	.....	.....
4	5.1	2.4	.8	.....	.....	.....	.....	.....	.....	29	.....	.....
5	6.1	3.0	1.5	.....	.....	.....	.....	.....	.....	35	.....	.....
6	7.1	3.7	2.2	1.1	0.1	.....	.....	.....	.....	40	.....	.....
7	8.0	4.5	2.9	1.7	.6	.....	.....	.....	.....	45	.....	.....
8	9.0	5.4	3.6	2.3	1.2	.....	.....	.....	.....	50	.....	.....
9	9.9	6.2	4.3	3.0	1.7	0.4	.....	.....	.....	53	.....	.....
10	10.8	7.0	5.0	3.6	2.2	.9	.....	.....	.....	57	.....	.....
11	11.7	7.8	5.7	4.2	2.7	1.3	.....	.....	.....	59	.....	.....
12	12.6	8.6	6.4	4.8	3.3	1.8	0.1	.....	.....	61	.....	.....
13	13.5	9.5	7.2	5.4	3.8	2.3	.5	.....	.....	63	8	18
14	14.5	10.3	8.0	6.0	4.4	2.8	.9	.....	.....	64	11	27
15	15.4	11.1	8.7	6.7	5.0	3.3	1.3	.....	.....	66	13	40
16	16.4	11.9	9.5	7.3	5.5	3.8	1.8	.....	.....	68	17	52
17	17.4	12.8	10.2	8.0	6.2	4.4	2.3	.....	.....	70	21	70
18	18.4	13.7	11.0	8.7	6.9	4.9	2.7	0.1	.....	71	25	88
19	19.4	14.6	11.8	9.3	7.5	5.5	3.3	.5	.....	73	28	110
20	20.5	15.5	12.6	10.0	8.1	6.0	3.8	1.0	.....	74	31	132
21	21.6	16.4	13.4	10.7	8.8	6.6	4.3	1.5	.....	76	34	160
22	22.7	17.4	14.2	11.5	9.3	7.2	4.9	2.0	.....	78	37	190
23	23.4	18.5	15.0	12.2	10.1	7.8	5.5	2.5	.....	79	40	230
24	25.1	19.5	15.9	13.0	10.8	8.5	6.0	3.0	0.3	81	43	270
25	26.6	20.6	16.7	13.8	11.5	9.6	6.6	3.5	.7	82	46	320
26	28.1	21.8	17.6	14.6	12.3	9.8	7.2	4.1	1.2	84	49	380
27	30.0	22.8	18.5	15.4	13.0	10.5	7.8	4.7	1.7	85	52	445
28	31.8	23.8	19.4	16.2	13.7	11.2	8.4	5.3	2.2	87	54	520
29	33.9	24.9	20.2	17.1	14.4	11.9	9.0	6.0	2.7	88	57	615
30	36.0	26.0	21.1	18.0	15.2	12.6	9.7	6.6	3.3	90	59	720

[1] Stump height assumed to be 1 foot.
[2] Merchantable length to a top diameter (inside bark) of 10 inches.
[3] Figured by Doyle rule, values curved.

Short-cut methods of approximating the contents of standing trees are often of use, as in the case of preliminary correspondence between buyers and prospective sellers. According to a very satisfactory method used by one firm in gaining a general impression of the amount, the owner is requested to send in a list of all trees offered for sale, giving the girth of each at 4½ feet above the ground and its length to the first living branch. The girth divided by 4 will give

approximately the diameter of the first 12-foot log inside the bark at the small end and the clear length will indicate whether the tree is a field or a forest grown walnut and will show to a certain degree how many logs may be expected. The size of the upper logs may then be estimated on the basis of the butt log. This method is simple and well adapted for the use of the walnut owner who wants to know approximately how much walnut he has.

WALNUT PLANTATIONS.

Walnut has always been a popular tree for planting on account of its attractive appearance, the value of its wood, the production of nuts, and the ease with which it may be propagated. Walnut has consequently been planted in every State in the country as single shade trees, as windbreaks, as open, orchardlike stands planted for nuts, or as closely planted stands for log timber. The last are found chiefly in the prairie regions from Ohio westward. There are 126 stands on record in Iowa alone, which is probably the leading State in this respect. Most of the plantations of this kind were established in the period of the great popularity of the wood, from the close of the Civil War to 1890, although at least one, in Missouri, dated back to 1836, and another, in Illinois, is said to have been planted in 1823. These plantations have improved the general appearance of the farms and have served excellently as shady groves for cattle.

FACTORS AFFECTING THE SUCCESS OF PLANTATIONS.

Many owners take special pride in their walnut plantations and maintain that these add to the market value of the farm. In most cases this is undoubtedly true, and the reasons are those mentioned above; but, because of lack of management, unfortunately many walnut plantations have not been successful as producers of valuable wood. The following table shows the average breast-high diameter growth in plantations, in comparison with the average for the natural stands of block walnut measured (Table 13), and with the slowest growth observed in a natural stand (see description of forest-grown stand in Fayette County, Ohio, on p. 23). The figures for growth in plantations are based upon measurements of 90 plantations.

This comparison of artificial with natural stands is not very favorable to the artificial. After the planted trees reach 50 years of age the growth is slower than that of the slowest observed in natural stands. Furthermore, the mediocre quality of the planted but unmanaged trees was in marked contrast to the clean, straight, very tall boles of the forest-grown trees. Two reasons may be assigned

for this prevailing inferiority of walnut plantations—either there was a poor choice of planting sites or there was wrong management of the planted stands, or both.

TABLE 13.—*Diameter growth in plantations, in comparison with average and slow growth in natural stands.*

Age (years).	Diameter, breast high (inches).		
	In plantations.	In natural stands—	
		Of average growth.	Of slow growth.
10	2.0	1.2	0.6
20	5.2	5.0	3.1
30	7.4	8.8	5.4
40	9.2	12.5	8.0
50	10.9	15.7	10.8
60	12.3	18.3	12.9
70	13.4	20.6	15.2
80	14.4	22.2	17.2

CHOICE OF PLANTING SITES.

The plantations of walnut in the prairie regions were quite naturally started in the situations in which the owners most needed trees; that is, on the treeless uplands or, occasionally, in recent years, on parts of cleared bottom lands. The sites selected were only rarely those which supported tree growth at the time of the settlement. The soil quality of these sites may be excellent, but the moisture present in the soil during the summer is insufficient for the flourishing growth of walnut.

As has been pointed out on pages 4 and 18, walnut needs for good growth a deep, fertile soil, both well watered and well drained, permitting the free movement of soil moisture and, at the same time, the access of air to the roots. These qualities are the more necessary the less favorable the climatic conditions, especially the precipitation. From Indiana westward soils suitable for planting are to be found principally in bottom lands, but bottom-land soils are in fact to be preferred even in the East. Swampy areas and places where cottonwood, willows, sycamore, or river birch form, or have formed, the chief growth will usually prove unsuited to walnut, though areas subject to floods for short periods, in which the backwater does not stand long in the depression, may form excellent sites. If the soil is a sterile sand, or if hardpan exists not far beneath the surface, as in parts of the Lake States, walnut can not be grown satisfactorily, even in the most favorable climate.

In the East, with its larger amount and better distribution of rainfall, much more freedom in the selection of planting sites is possible than in the prairie regions or in the Lake States. In the limestone regions of Tennessee, Kentucky, West Virginia, and the northeastern part of the range in general, cut-over lands and even rocky hillsides,

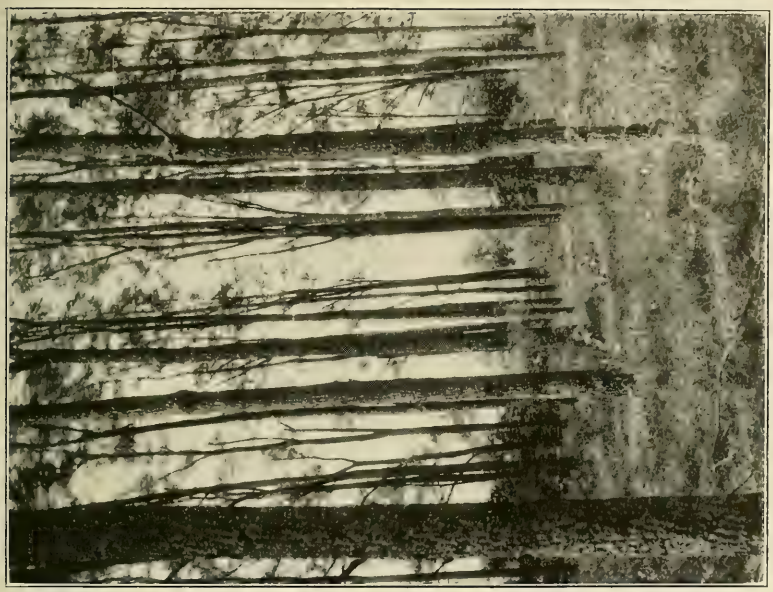

FIG. 2.—GOOD SOIL.

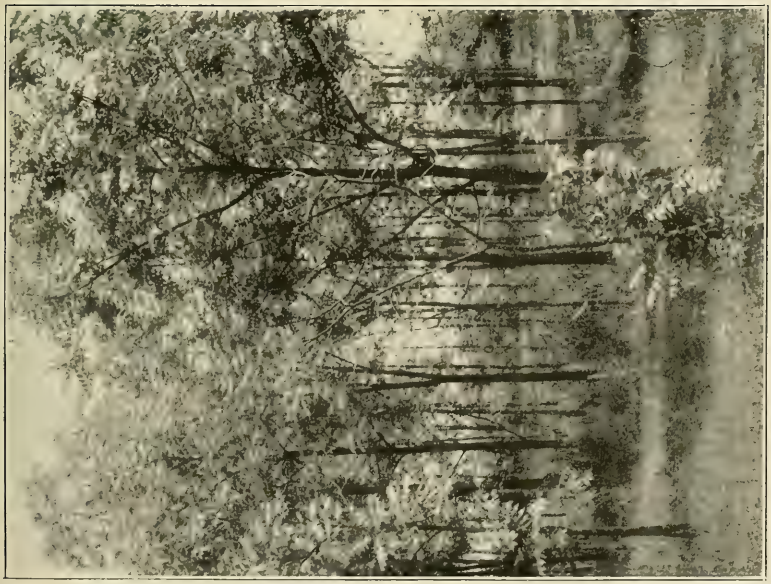

FIG. 1.—POOR SOIL.

EFFECT OF SOIL QUALITY IN AN INDIANA BLACK-WALNUT PLANTATION.

FIG. 1.—PLANTATION OF BLACK WALNUT IN HOWARD COUNTY, IND. THE TREES ARE CLOSELY SPACED, AND THOSE STANDING ALONG THE OUTER EDGE MEASURED LARGER IN DIAMETER THAN THOSE INSIDE.

FIG. 2.—BLACK-WALNUT PLANTATION, SHOWING CLEAN STEMS MADE BY HIGH PRUNING.

if erosion is not actively taking place, are promising sites for the successful growth of walnut. Similarly, the level, rolling country of southeastern New York, eastern Pennsylvania, and New Jersey west of the sandy parts, where the soils are deep, present favorable sites for walnut. Western Maryland and the Shenandoah Valley of Virginia are generally well suited, but eastward to the coast the soils are usually not adapted, although occasional sites on river bottoms or rich flats are excellent and have produced walnut shade trees of large size. In North Carolina, South Carolina, and northern Georgia, except in the mountain region, it is doubtful if the climatic conditions are best for walnut. The species range almost to the Gulf and has been planted as an ornamental tree in Florida, where phenomenal crops of nuts are reported; but often in this region the tree is poor in quality and becomes defective at an early age. The planting of walnut for its wood in most of North and South Carolina, Georgia, Alabama, and Louisiana is problematical, because there has been no experience with actual plantations in that region.

The best criterion for determining a planting site, either in the East or West, is whether walnut grew on the site naturally and made a good development. If it did, planting is safe; if it did not, the planting may be successful with good management, but there is an element of uncertainty involved.

The soil needed for the most satisfactory production of merchantable stands of walnut is nearly everywhere the best agricultural soil. Placed on a strictly economical basis, there is little argument for growing walnut for wood production on these soils. Tillotson[1] shows the net annual yield for 12 plantations from 12 to 42 years of age scattered from Indiana to Iowa. The best stand shows an annual income of 91 cents an acre; the poorest, a loss of $1.50 an acre annually, while the average plantation shows a loss embodying failure to pay taxes and interest charges on the expense of establishment. In the States in which walnut is of chief importance the gross income from farm crops amounts annually to about $15 an acre. Excluding all interest charges, it would be necessary to have about 65 thousand feet, board measure, to the acre at the end of 75 years in order to yield an equal gross annual income. According to the most optimistic estimates the amount would hardly be 20 per cent of this. There is no point in giving up good agricultural land that can be used as such to the growing of walnut for wood only.

MANAGEMENT OF PLANTED STANDS.

Walnut is intolerant of shade, and this is an important item in its management, disregard of which is one of the causes of the unsatis-

[1] "Forest Planting in Eastern United States," by C. R. Tillotson, Bulletin 153, United States Department of Agriculture, p. 31.

factory development of plantations. It affects the crown density and directly limits the number of trees to the acre under which the proper growing conditions may be maintained and the best material produced. The number of trees to the acre required to maintain a continuous crown cover is, of course, largest in the early history of a plantation and decreases with age, either naturally, through the crowding out of the less rapid growing individuals, or under management through their removal in thinnings. In the case of walnut close spacing (see "Spacing," p. 42) at the start is more practicable than with many other species, because of the relatively low cost of nuts and planting. This close spacing tends to reduce, although it can not always prevent, the profuse branching of the trees at a height of about 6 feet. When, however, the crowns commence to crowd each other badly, some beginning to take the lead and others to fall behind, it is poor economy to maintain such a density, and thinnings become imperative. Left to themselves, these even-aged plantations develop so uniformly that the dominant trees do not much exceed their lesser neighbors in height, the thrift of the whole stand is lowered by mutual suppression, and the stand is in a condition of stagnation. Ultimately, the crowns become very much reduced and stag headed, and water sprouts come out profusely on the trunks. These water sprouts grow slowly until the tree dies or is released by the death of neighboring trees; whereupon the sprouts take a new lease of life, and the tree develops into a topless branchy stub of no use for any purpose.

The combined effects of poorly chosen site and overcrowding are shown in a plantation in Jackson County, Mo. Although the plantation is 82 years old, few of the trees are merchantable. The stand is situated on a hilltop, which, in this western region, is too dry for walnut; consequently, the trees of the outermost row, exposed to full light on one side, have poor development, branch low, and are practically worthless. The effects of overcrowding upon the condition both of the trees inside the plantation and of those in the outer row may be summarized as in Table 14.

TABLE 14.

	Average diameter breast high.	Percentage of total number of trees.		
		Healthy.	Water spouted.	Decayed.
	Inches.			
Outer row	17.1	65	18	17
Inner trees	12.7	34	63	3

In a plantation 31 years old in Howard County, Ind. (Pl. V, fig. 1), the outer trees averaged 8.3 inches in diameter, breast high, and the inner trees only 7.4 inches. There were 342 trees to the acre in this plantation, although experience indicates that 300 to the acre is full stocking at this size. Natural groves seldom contain over 60 trees to the acre at 60 years of age.

Pruning.—Walnut trees may be pruned with profit, the object being to obtain clean, straight boles. Logs from such trees are distinctly more valuable. Before the war knotty logs usually brought $20 to $25 a thousand board feet, f. o. b. cars, shipping point, regardless of size, and smooth logs were paid for on a sliding scale of prices, the lowest of which was better than the flat price for cull logs. In average logs the difference was about $20 a thousand board feet. If pruning will double the value of a log, it is certainly a paying proposition. The spreading tendency of the walnut tree and its intolerance of shade make pruning to some extent necessary even in the best-managed stands. Limbs that support essential parts of the crown should not be taken; but smaller branches and low limbs that will ultimately be crowded out should be cut to hasten the natural process and give more clear wood in the log. The pruning should be flush with the trunk, and care should be taken not to injure the trunk. The saw is ordinarily the best instrument to use. The first cut should be from beneath, and should sever bark and wood sufficiently to prevent peeling of the trunk when the branch drops. A second cut made from above then severs the branch. It is well to prevent the subsequent infection of the wound with the germs of decay by painting it with tar or with a good water-resisting paint.

PROBABLE YIELDS FROM PLANTATIONS.

As there are few plantations in this country that have grown up under ideal soil conditions and have been properly tended, it is impossible to judge future yields of logs from actual examples of plantations, and all natural stands are spaced so irregularly that they do not represent maximum productivity any more than do the overcrowded plantations. The growth in value of individual trees may be estimated, however, on the basis of the prices current in the year 1918. Table 15 shows the values of trees of different sizes delivered at the railroad. Except when they were close to shipping points, it was not profitable in 1918 to cut trees under 17 inches in diameter.

It is apparent from Table 15 that the value of walnut increases rapidly with age, partly because it holds up its increment well, but more on account of the sliding scale of prices for logs that is everywhere in vogue for this species, and which places a decided premium

on large logs. Trees in plantations, therefore, should be grown as long as they appear sound and healthy. Of course, it is impossible to tell at this time what scale of log prices will be used 150 years hence, but, nevertheless, the plantation should be managed with a long rotation in mind.

TABLE 15.—*Value of individual trees.*[1]

Diameter breast thigh.	Volume board feet.	Value at railroad.[2]	Age.	Diameter breast thigh.	Volume board feet.	Value at railroad.[2]	Age.
Inches.			*Years.*	*Inches.*			*Years.*
13	18	$0.36	42	22	190	$8.20	79
14	27	.54	45	23	230	10.80	85
15	40	.75	48	24	270	13.80	92
16	52	1.00	51	25	320	17.30	100
17	70	1.70	55	26	380	21.50	110
18	88	2.40	59	27	445	26.50	121
19	110	3.40	63	28	520	32.20	132
20	132	4.70	68	29	615	39.90	147
21	160	6.10	73	30	720	49.00	.....

[1] This table applies to individual trees in groves or open woodlands and not to trees grown singly in the open field. The prices were those current in the year 1918.

[2] As the stumpage price is so variable, depending upon the length of haul, the value of the trees delivered at the railroad is the most constant figure that may be given. Stumpage value may be figured by subtracting cutting and hauling expenses from the value of the logs delivered.

The number of trees on a well-managed plantation will at all times show the maximum that can be grown to the best advantage. The reduction from year to year will be accomplished by frequent thinnings and will not be left to the processes of nature that lead to excessive mutual suppression and to stagnation of growth. Such a plantation on good soil should yield logs somewhat as shown in Table 16. The calculation is believed to be conservative for the Ohio Valley and northeastern region, but possibly it is somewhat high for the trans-Mississippi States, where height growth is not generally so good and where merchantable length is, therefore, somewhat less.

TABLE 16.—*Possible yield of black walnut plantations.*

Age (years).	Average diameter breast high (inches).	Number of trees per acre.[1]	Board feet per acre.	Value per acre.[2]
10	1.2	2,700	.....	.....
20	5.0	700	.....	.....
30	8.8	280	.....	.....
40	12.5	160	.....	.....
50	15.7	100	4,800	$83.00
60	18.3	85	8,500	229.50
70	20.6	70	10,500	387.80
80	22.2	65	13,000	566.80
90	23.8	55	14,300	726.00
100	25.0	50	16,000	865.00

[1] Derived from Table 1, p. 2, Farmers Bulletin 711, "The Care and Improvement of the Woodlot," by C. R. Tillotson.

[2] Based on the value of logs delivered at the railroad and not on the value of the stumpage, as the latter is too largely conditioned by cutting and hauling expense.

If a plantation, initiated with wider spacing, is left to grow into merchantable timber, the production will be less than that indicated

above. In the first place, the height and merchantable length will be less, on account of the lack of close spacing in youth; in the second place, the clear length will be less and the quality poorer and, therefore, the prices will be less; and, in the third place, after about 30 or 40 years the diameter growth will be smaller, as the trees will have begun to crowd each other, unless they were planted very far apart. With an initial spacing of 6 by 16 feet, making about 450 trees to the acre, a thinning will be necessary in about 30 years. Even if the stand is not thinned at this time, the taller and more thrifty trees will probably have sufficient light to become merchantable, although they will be inferior to trees that have had the proper care all their life.

Open-grown trees or orchards planted for the sake of the nuts will naturally have a more rapid growth in diameter, but will have less clear length. The value of such open-grown stands will manifestly be incidental to the production of nuts (see "Production of Nuts," p. 37).

In the West, black walnut is planted to some extent on irrigated land for windbreak and ornamental purposes as well as for the yield of nuts. The logs are not likely to find a very ready sale, as the freight rates to all mills that specialize on walnut are excessively high, amounting to $50 a thousand board feet or more; and it is unlikely that the amount of timber in any one place will justify cutting by local mills. Growth under these conditions is apparently very much the same as in the prairie States.

Two plantations offer the comparisons shown in Table 17, one being a wide-spaced plantation in eastern Illinois, in which the trees are 6 by 16 feet apart, and the other a windbreak near Ogden, Utah. The plantation in Illinois is located on a rise several hundred yards from a stream, and, as there never was any natural tree growth on the area, it is possible that the site is too dry for walnut. The soil is rich black prairie loam. The spacing of the trees is very wide, and there is little difference in diameter between marginal trees and those within the stand. The plantation in Utah is situated along an irrigating ditch, in which water is flowing during practically the entire growing season.

TABLE 17.

	Age (years).	Average height (feet).	Diameter, breast high (inches).		
			Average.	Largest.	Smallest.
Illinois	51	55	12.8	21.6	7.0
Utah	52	55	12.1	23.2	3.5

PRODUCTION OF NUTS.

Although growing walnut for the sake of the nuts produced is a matter of horticulture rather than of forestry, it is necessary to take this source of income into consideration in dealing with this species

as a wood producer. It is, of course, impossible to get a maximum yield of walnuts and of wood at the same time, because the former demands a wide spacing that will give low wide-spreading crowns exposed to full sunlight, and the latter calls for a closer spacing with consequent limitation of the individual crowns and of the amount of fruit produced. In the average grove planted for general utility as scattered trees or small clumps, the walnuts will be a by-product of some value, either for family use or for sale. In some sections the growing of trees for the nuts only may be more profitable, and the logs produced in small numbers will be of secondary importance. Table 18 contains the statistics of the Thirteenth Census (1910) upon the production of walnuts.

TABLE 18.—*Production of walnuts, by States, according to the Thirteenth Census (1910).*

State.	Bearing trees.	Under bearing size.	Bearing trees per farm reporting.	Nuts per bearing tree.	Price per pound.	Income per tree.
				Pounds.	*Cents.*	*Cents.*
Alabama	3,228	1,753	3.1	48.8	2.2	107.5
Arizona[1]	(2)					
Arkansas	9,104	5,640	9.2	56.4	1.5	84.5
California	6,582	7,905	27.2	24.2	1.6	37.5
Colorado[1]	(2)					
Connecticut	3,188	2,636	12.6	14.2	4.1	58.2
Delaware	890	554	3.4	39.5	1.6	63.2
Florida	470	2,855	2.5	90.7	1.8	163.3
Georgia	6,850	2,258	3.8	62.4	2.1	131.0
Idaho[1]	(2)					
Illinois	44,159	24,698	24.7	12.0	1.4	16.8
Indiana	11,848	4,822	12.9	31.9	1.2	38.2
Iowa	125,194	24,277	31.7	9.1	1.8	16.4
Kansas	113,537	8,619	60.6	3.3	1.6	4.8
Kentucky	14,521	2,360	15.8	54.8	1.4	76.7
Louisiana	616	655	4.0	88.7	1.8	159.5
Maine	231	63	7.2	6.9	3.1	21.4
Maryland	5,375	1,522	5.3	51.2	1.1	56.4
Massachusetts	1,910	434	6.8	20.9	3.0	62.7
Michigan	16,105	3,520	6.7	33.9	1.4	16.8
Minnesota	3,459	922	21.9	24.9	1.9	47.3
Mississippi	2,914	2,391	3.6	52.0	2.4	124.8
Missouri	85,330	15,199	21.6	28.7	1.0	28.7
Montana[1]	(2)					
Nebraska	78,296	36,526	50.4	4.9	2.3	11.3
Nevada[1]	(2)					
New Hampshire	1,518	208	9.6	8.8	2.8	24.6
New Jersey	4,168	804	3.9	36.3	1.8	65.4
New Mexico[1]	(2)					
New York	19,782	2,815	7.0	23.6	2.5	59.0
North Carolina	19,570	9,180	5.0	55.3	1.5	83.0
North Dakota[1]	(2)					
Ohio	8,693	3,399	9.2	40.8	1.3	53.0
Oklahoma	21,412	7,204	45.6	4.4	1.7	7.5
Oregon	2,024	3,405	7.8	34.2	1.9	65.0
Pennsylvania	65,075	22,193	4.7	33.3	1.8	60.0
Rhode Island[1]	(2)					
South Carolina	3,662	2,258	3.7	50.6	2.0	101.2
South Dakota	16,726	10,219	54.0	4.4	2.0	8.8
Tennessee	18,225	3,536	14.2	38.9	1.3	50.5
Texas	1,820	1,206	6.5	30.5	1.8	55.0
Utah[2]	(3)					
Vermont	1,704	253	15.5	19.3	2.2	42.5
Virginia	23,049	9,173	8.9	26.1	1.6	41.7
Washington	1,427	601	13.7	30.5	1.6	48.6
West Virginia	32,495	9,682	24.4	27.0	1.3	35.5
Wisconsin	3,459	922	10.4	24.9	1.9	47.3
Wyoming[1]	(2)					

[1] Species reported as occurring, but no further information available.
[2] Reported.
[3] Although they are not reported in the census, there are bearing trees with salable product in Utah.
[4] Not reported.

According to these figures there is a great difference in the yields of walnut trees in different parts of the country. In the Prairie States the yield is notably low, ranging from 3.3 pounds to the tree in Kansas to 12 pounds in Illinois. Through the Lake States, the Ohio Valley States, and the Eastern States the yield runs from 25 to 40 pounds, and in the Gulf States and the Carolinas it is reported to be 50 to 90 pounds. These differences may not be due so much to climatic causes as would at first appear. The lowest yields are from regions in which the most trees are reported and in which walnut flourishes naturally. It is probable that in this region many of the trees are of natural growth, in mixture with other hardwood species that would tend to reduce the production. In the Gulf States, in which the maximum yields are reported, the trees are practically all planted. Furthermore, the reports are in all probability mostly from single trees planted in the open; and this would account, in some measure at least, for the high yields. The prices are much more uniform than the yield, indicating that they are dependent not so much upon demand as upon the minimum cost of production and marketing. This cost ranges from 1 cent a pound in Missouri to 2½ cents in New York. In the New England States, where walnut is not native, but is planted to a limited extent, the prices are still somewhat higher than in New York. The maximum income per tree, naturally therefore, comes from the region of greatest yield of nuts per tree. The income and yield are both highest in the South and lowest in the Prairie States.

Of all the nut trees that may be planted, black walnut is probably the best in all the region from Tennessee and western North Carolina northward and eastward to the limits of the natural growth. Even here, however, the nut-growing business is so unorganized that it is difficult to say what value it has to the farmer. Certainly this crop is not able to compete with general agricultural crops on the high-class soils demanded for the growth of walnut at the present time, in spite of the fact that the costs of labor in growing and handling the crop are lower than the costs for handling agricultural crops.

The culture of black walnut is similar to that of pecan and English walnut, which it resembles in soil and light requirements. Seedling walnuts usually begin to bear at about 20 years of age and continue in full vigor for a long period. Grafted trees usually begin to bear much earlier, but it takes 10 or 12 years for the development of sufficient crown to allow a heavy production of nuts. At present there are several horticultural varieties in the market budded from trees that have exceptionally good nuts for cracking, but there are few bearing trees from such stock and it is difficult to forecast their yields and value.

Trees planted to the north of the natural range of black walnut bear small numbers of nuts, and the size is below normal, although the quality is reported to be as good as farther south. It has been the experience in England that this kind of nuts give rise to weak seedlings and should not be used for propagation purposes.

ESTABLISHING WALNUT PLANTATIONS.

METHODS OF PLANTING.

Walnut may be grown successfully either directly from the nuts sown where the plantation is to be made or from young nursery stock. Growing walnut directly from nuts is naturally much the cheaper method. The nuts may usually be gathered at simply the cost of the labor. They could be bought, even on the retail market in 1918, for 7 cents a pound, or approximately $2.50 for 1,000 nuts. One-year-old seedlings from a nursery would, on the other hand, cost $15 to $20 a thousand. The proportion of nuts failing to germinate would usually be about equal to the first year's loss with nursery stock. On this score there is, therefore, no advantage in the more expensive stock. In starting the stand from nuts the chief danger has been that, as planting is usually done in the fall, the nuts would be destroyed by rodents during the winter. If squirrels and mice are not plentiful, however, this is the cheapest and simplest method.

The nuts are gathered in the fall after they have dropped naturally from the trees, and may be planted immediately, before the ground freezes, without being shucked. They should be placed in shallow holes made with a mattock, so that they will lie about an inch and a half deep. When, as will often be the case, the planting is in sod, it may be facilitated by first plowing furrows, in which the nuts may be planted at regular intervals. This also permits a better early development of the seedling by freeing it from competition with weeds and grass. If plowing is not practicable, the sod should be removed with a spade or mattock for a foot about the spot where the nut is planted. To insure a full stand of seedlings from the beginning, it is best to plant two nuts in each hole, for some of the nuts planted will not germinate at all and some not until the second year. If the nuts are of usual quality, however, 80 per cent will germinate within two years, and a great number of spots will have two trees in them. By the third or fourth year, when the seedlings are well established, even if both appear vigorous and of equal development, they must without fail be reduced to one tree to the spot, or the thrift of the trees will soon suffer.

If there is danger from rodents, or if it is desired to allow hogs to run on the planting site during the fall and winter, the nuts may be planted successfully in the spring. Spring planting requires more

FIG. 1.—BLACK-WALNUT REPRODUCTION ALONG A FENCE ROW IN INDIANA.

FIG. 2.—TO A CONSIDERABLE EXTENT HOGS PREVENT THE REPRODUCTION OF BLACK WALNUT.

FIG. 1.—SPROUT REPRODUCTION FROM ROOT COLLAR.

FIG. 2.—SPROUT REPRODUCTION THAT HAS BEEN FOLLOWED BY BUTT ROT.

care and is more bothersome, but it avoids the rodent problem without making necessary the purchase of expensive nursery stock. After the nuts are gathered in the fall they should be stored for the winter by "stratifying"; that is, they should be placed in layers separated by moist sand, either in a rodent-proof pit in the ground or in a box in a cool cellar, or some such place. Freezing once or twice is not detrimental, but repeated freezing and thawing while the nuts are in the moist sand will cause the death of the seed. The sand must be kept moist, particularly toward the spring, the time for germination to take place. The nuts must be carefully watched at this time. When they split and the radicles appear it is time to plant. The stratified nuts are dug up, and those showing growth are carefully placed in baskets for planting. Sometimes the shells are loose, and the radicles somewhat developed; considerable care is then needed in handling and planting these nuts to prevent fatal injury. A shallow hole should be dug with a mattock in either a plowed furrow or seed spot cleared of grass, and a single nut should be placed in each hole, with the radicle pointed down. The nut should be covered about 1½ inches deep, and the soil should be firmed over the top with the foot. Some of the nuts will remain in stratification, because germination either has been delayed or has entirely failed. These nuts should be put back in the sand and left for possible use the next spring, for, even with the most careful handling, there will be some unoccupied spots in any plantation. These vacancies may be filled the following spring from the supply of nuts in stratification, the sprouting of which may have been delayed until then. Because of the short time between planting and the appearance of the young trees, and because of the abundance of other natural foods in the spring, the danger from squirrels is a negligible factor, and the planting of nursery stock or home-grown trees is very rarely necessary.

Planting walnut seedlings is rarely warranted, in view of the two cheap and simple methods above described. The expense involved in planting seedlings is greater than in the case of many other tree species, because of the long taproot which even 1-year-old trees possess. If for any reason it is desirable to plant seedlings instead of nuts, it is not difficult to grow them in a nursery. Nuts may be planted in the fall in a bed prepared as for any garden crop. They should be spaced 2 or 3 inches apart in rows 6 inches apart. The seedlings should be cultivated and cared for during the first year, and should be set out the following spring in their permanent places, in large, deep, properly spaced holes. Care must be exercised in the transplanting because of the length of the young taproot. A seedling left in the nursery bed for longer than one year will develop such a

deep-feeding root system that transplanting soon becomes very expensive and is liable to result in injury to the roots and, possibly, in the subsequent death of the seedlings.

SPACING.

The spacing depends altogether upon the kind of plantation the owner intends to have. If he intends to bestow careful management upon his trees and get the best results from them, the initial spacing should be close (4 by 4 feet), and thinnings should also be made without fail when the crowns begin to interfere with one another. If, on the other hand, the owner plants the trees as a side line, to add to the appearance of his farm, protect his stock, or occupy some out-of-the-way corner, and if it is his intention to let them develop as they will, a much wider spacing is advisable—say 6 by 16 feet. If they are planted closer the trees are liable to enter into active competition before they become merchantable. If they are uncared for they will so interfere with each other that after a time none will have much value; in extreme cases, decay and death may overtake the trees before they are merchantable. If the trees are grown for the production of nuts, a spacing of 50 to 60 feet would be advisable.

Although walnut is too coarse branched and thin foliaged to make a first-class windbreak, it may sometimes be desirable to plant it in single rows for this purpose. In single rows close spacing is admissible even if it is not expected that the trees will be carefully managed, for plenty of side space will be available. A spacing of 4 to 6 feet apart in the rows is satisfactory. In pastures walnut trees may be planted singly or in groups. If the trees are planted singly, a typical low-crowned spreading tree will develop that would yield one short log. This log would not be of high value, but, nevertheless, it would be merchantable. In groups of a dozen trees or so some of the trees in the middle of the group ought to produce very good logs—not of forest-grown form, it is true, but, nevertheless, superior to single trees grown in the open. Whenever planting is done the plans should provide for the maturing at one time of 40 trees at least. It is to be borne in mind that in a close plantation 80 per cent of the trees will be cut in thinnings before maturity. If he has at least 40 trees maturing at once, the owner is assured of a market at any time and a better price, as those trees will make at least 4 thousand board feet, or one carload of logs.

PROTECTION FROM GRAZING.

General grazing is not likely to harm a well-established plantation, provided too many live stock are not permitted on the area and no part of it is made to serve as a feed lot. New plantations, how-

ever, should be protected from grazing for a period sufficiently long to allow the trees to become reasonably safe from damage. The period of protection from hogs should be about three years; from cattle and horses, not less than 10 years. The farmer should, however, be cautious; and, if grazing that has been started in a plantation at the end of the tentative period of protection appears to be damaging the trees, the stock should be removed for a year or two longer. Damage from grazing results more from breakage of the trees and from trampling and compacting of the soil than from actual browsing. In one plantation in Indiana, for example, there is a large opening which resulted from the feeding of corn to hogs, a procedure that was continued through many years. The excessive trampling and compacting of the soil, together with the unusually large accumulations of manure at one place, killed out the trees. By wallowing in the depressions about the trees and laying bare the roots, hogs occasionally damage trees planted in low, moist parts of pastures. For this reason trees planted singly in pastures should be set on the slight rises or slopes rather than in the hollows. On account of the better drainage these sites dry off quickly after rains, instead of holding pools of water or mud about the roots of the trees; and consequently they provide better shade places for cattle.

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DAMPING-OFF IN FOREST NURSERIES.

By Carl Hartley, formerly *Pathologist, Office of Investigations in Forest Pathology.*

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DAMPING-OFF IN GENERAL.

Damping-off is the commonest English name for a symptomatic group of diseases affecting great numbers of plant species of widely separated phylogenetic groups. It is commonly used for any disease which results in the rapid decay of young succulent seedlings or soft cuttings. Young shoots from underground rootstocks may also be damped-off before they break through the soil (66).[1] The same term is even used for diseases affecting the prothallia of vascular cryptogams (2). The name apparently originated in the fact that the disease is usually most prevalent under excessively moist conditions. In those cases in which the disease becomes serious without the presence of unusual amounts of moisture the term is a misnomer. It is, however, so thoroughly established in practical use that it would be impossible, even if desirable, to establish any other name.

[1] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

While the parasites reported as causing damping-off are probably not as numerous as the host species which are subject to it, a considerable number are known. Two quite different types of damping-off parasites may be recognized. In the first type we have fungi, such as *Pythium debaryanum* Hesse and *Corticium vagum* B. and C., soil inhabiting and primarily saprophytic, which attack a great variety of hosts, and are at least better known, if not more destructive, as damping-off organisms than as parasites on older plants. They are specialized as to the type and age of tissues which they attack rather than as to host. The second type includes fungi less common as saprophytes and with a relatively limited, sometimes very closely limited, host range. *Phoma betae*, the systemic parasite of sugar beet (37), is an excellent example of the host-specialized parasite, transmitted in the seed and capable of seriously injuring various parts of the older plant at different stages of growth as well as attacking seedlings.

Most damping-off parasites are intermediate in habit between the extremes of these two types. Of those which are somewhat host specialized, the following may be mentioned:

Phomopsis vexans, the cause of foot-rot of eggplant, reported by Sherbakoff (128) as a frequent cause of damping-off of this host and believed to be carried on seed.

Gibberella saubinetii (Mont.) Sacc. (29) and the imperfect fungi which kill grain seedlings as well as cause diseases of the older plants (80; 126, p. 218). Species of Gloeosporium and Volutella named by Atkinson (2, p. 269; 52) as able to kill seedlings or cuttings of particular host plants.

Glomerella (*Colletotrichum*) *gossypii*, described by Atkinson (1) and Barre (4) as likely to cause damping-off of cotton (112).

Fusarium lini, the flax parasite, reported by Bolley (14) as destructive to young seedlings.

Phoma lingam, the cause of black-leg of cabbage, at least under inoculation conditions able to kill quickly seedlings of cabbage and other crucifers (72).

Peronospora parasitica (Pers.) De Bary, a downy mildew attacking cabbage and various other crucifers, reported as killing thousands of very young cabbage plants in Florida seed beds (41).

The entomophthoraceous *Completoria complens*, on fern prothallia (1; 87, p. 203).

Bacillus malvacearum, a parasite of the leaves of cotton plants, which can also cause damping-off of its favorite host (113) and the bacteria from diseased cucumber plants with which Halsted (53) caused typical damping-off of cucumbers.

Damping-off fungi with wider host ranges include *Phytophthora fagi*, *Aphanomyces levis* (100), *Rheosporangium aphanidermatus* (38, 39), *Botrytis cinerea*, and certain Fusaria. The so-called propagation fungus, "vermehrungspilz," a sterile damping-off mycelium which Sorauer (133, p. 321) believed related to Sclerotinia and for which Ruhland (115) has erected a new genus, considered by both

authors the most serious enemy encountered in growing softwood cuttings in Germany, if distinct would be a further addition to these generalized parasites. However, it is now believed (34) to be identical with *Corticium vagum*. Common generalized parasites of older plants, such as *Sclerotinia libertiana*, *Sclerotium rolfsii* (129), and *Thielavia basicola* (47), capable of attacking roots or other parts of older plants of numerous species, may also be considered among the damping-off fungi when they cause the death of small seedlings, as occurs, for example, in attacks by *Sclerotinia libertiana* on lettuce (20, p. 28) and celery (103, p. 536) in seed beds. Further study will probably result in multiplying almost indefinitely the number of more or less important damping-off parasites, both of the specialized and unspecialized groups, although the most important of the latter type are probably already known.

Most of the references in literature to damping-off describe its occurrence in truck crops and the losses caused in these crops. According to Halsted (53, p. 342), weed seedlings are also very commonly attacked. Duggar (33) names lettuce, celery, cotton, sugar beet, cress, cucumber, and sunflower as especially susceptible to injury by the two most important damping-off organisms. Except for the plant species in which damping-off by seed-carried parasites is common, it appears that the economic damage from damping-off is serious only with plants whose culture involves the raising of the seedlings in crowded seed beds for subsequent transplanting. For example, tomatoes do not ordinarily suffer from damping-off in the field (70), but the growing of seedlings in flats for subsequent transplanting is sometimes seriously hampered as a result of the prevalence of damping-off. This same principle holds in general for trees. Broad-leaved trees, which are usually not as crowded in the seedling stage as are the conifers, seldom give rise to complaint on the score of damping-off. The conifers, subject to serious losses in nursery beds, are not believed to be greatly affected in this country by the better known types of damping-off under forest conditions (68) except in the less common cases in which seedlings come up in close groups from squirrel hoards, artificial seed spots, or similar sources.

A considerable number of broad-leaved trees have been reported at one time or another as injured by damping-off, though complaints of commercially serious losses are not common. The cases which have come to the writer's attention are listed below:

Cause not determined:

Orange (43, 108).

Olive, in greenhouse at the University of California.

Russian wild olive (*Elaeagnus* sp.), serious at an Iowa nursery; oral report by Mr. C. R. Bechtle, formerly of the United States Forest Service; at another nursery in the same region this plant was reported as very little subject to injury.

Cause not determined—Continued.

Magnolia (31), troublesome if the pulp is not washed off the seed before planting.

Eucalyptus spp. (88, p. 45; 131), serious under moist conditions.

Betula spp. Communication by Dr. Perley Spaulding, of the Bureau of Plant Industry; found especially susceptible in a Pennsylvania nursery.

Carob, at United States Plant Introduction Garden, Chico, Calif. Dr. Mel T. Cook states that damping-off is more serious in carob seedlings if the seed is removed from the pod than if pods and seeds are sown together.

Robinia pseudacacia (13).

Apple, in greenhouse at the Michigan Agricultural College.

Sclerotinia sp. (Europe):

Betula (79), a disease of seed and germinating seedlings.

Phytophthora fagi (Europe):

Fagus. Hartig (59) and many other writers; seriously affected, even in forest.

Platanus (15).

Acer (15), *A. platanoides* and *A. pseudoplatanus* (86, 104).

Robinia (59, 73).

Fraxinus (73).

Acacia (59).

Cercospora acerina (Europe):

Acer platanoides and *A. pseudoplatanus* (58).

Pythium debaryanum:

Tilia europea and *T. ulmifolia* (137), serious.

Robinia (75, p. 13–14), killing germinating seed.

Catalpa (126).

Rhizoctonia:

Citrus seed beds (130); much loss.

Catalpa (126).

Botrytis cinerea:

Catalpa (126).

Fusarium sp.:

Citrus seed beds (130); much loss.

The sugar beet is apparently the only plant whose damping-off diseases have been investigated with any degree of completeness by modern methods. While there is a great mass of literature on damping-off, it is mainly descriptive and on control measures. Most of the reports of the causal relation between the different fungi and the disease in the various host plants have been based on demonstrations of the presence of the fungus in diseased seedlings. In a great number of these cases identification has been doubtful. Even when a fungus is known to belong to a parasitic species, it is by no means certain that the mycelium found belongs to a parasitic strain. It has been found, for example, that only part of the strains of *Corticium vagum* occurring in sugar beets are able to attack that host vigorously (38, p. 154). Similar data for pine appear in figures 1 and 2. Furthermore, even parasitic strains of several of the damping-off organisms are so widely distributed as

saprophytes that one of them might easily get into a killed seedling after some other parasite had caused its death. Not only in the case of seedlings killed by fungi like *Peronospora parasitica*, but in

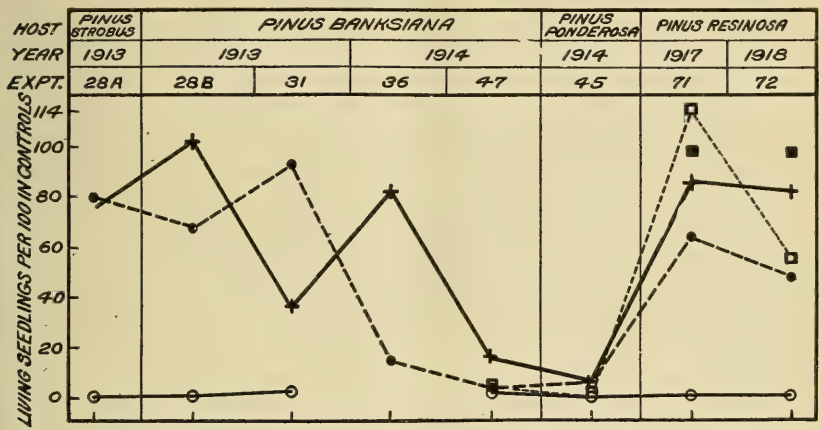


FIG. 1.—Diagram showing the relative activity of different strains of *Corticium vagum* in inoculations made at the time of sowing the seed. In experiments Nos. 36, 45, and 47 the values are plotted for the number of seedlings appearing above the soil. For the other experiments the number of seedlings surviving at the close of the experiment have been taken. Explanation of symbols: ○=Strain 147, from spruce seedlings, Washington, D. C., 1910; +=strain 50, from pine seedlings, Nebraska, 1909; □=strain 233, from *Elaeagnus* sp., Kansas, 1913; ■=strain 230, from the same lesion as strain 233; ●=strain 183, from bean, New York, 1910.

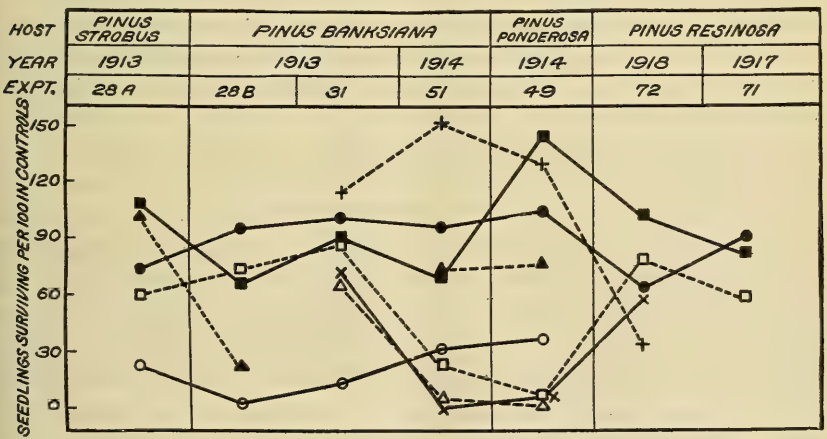


FIG. 2.—Diagram showing the relative activity of different strains of *Corticium vagum*, as indicated by the number of seedlings surviving in inoculated soil. Explanation of symbols: ●=Strain 189, from sugar beet, Michigan, 1910 (light-brown mycelium with few sclerotia); ▲=strain 211 and △=strain 212, from sugar beet, Colorado, 1910; ■=strain 186, from potato, Ohio, 1910; □=strain 187, from potato, New York, 1910; +=strain 205, from Douglas fir, Colorado, 1911; ×=strain 192 and ○=strain 206, from pine, Nebraska, 1911.

cases of true damping-off produced by the rotting type of parasite, much of the rapid decay of the seedling after death is brought about by bacteria and fungi other than the one causing death.

Inoculation experiments are therefore probably even more necessary in damping-off investigations than in studies of most other diseases in order to demonstrate etiological relationships. Unfortunately, most of the inoculation work with damping-off organisms prior to 1900 was either crudely done by placing diseased seedlings against healthy ones or consisted of experiments in which purity of cultures and validity of controls did not receive sufficient consideration. Recent investigations not primarily directed toward damping-off, but which have decidedly increased our knowledge of the relation between Corticium and the disease, are those of Peltier (98) and Fred (43). The latter established a strong presumption that the difficulty in securing stands of various field crops having oily seeds in soil where green manures had been recently turned under is due to the killing of the sprouting seed by damping-off organisms.

In tobacco, sugar beet, and pine, whose damping-off has received considerable attention, it has been found that the damping-off proper is commonly preceded by the killing of many of the sprouting seeds in the soil (38; 68, p. 522; 81, p. 5) and followed, after the plants become too large to be killed by the damping-off organisms, by root sickness and the death of small roots (38, p. 161; 64; 100). This latter has been reported also as a serious matter in the case of *Corticium vagum* for potato (51), a host on which damping-off is not important because of the lack of commercial propagation from seed. *Pythium debaryanum* further has been reported as continuing to work in the cortical tissues and leaves of tobacco plants which have been infected too late to result in death (81).

The fact that a number of the damping-off fungi are able to attack young or soft tissues of so great a variety of plants and are much less able to kill older plants suggests that resistance to damping-off may be in part based on purely mechanical factors. Hawkins and Harvey (71) recently have extended to *Pythium debaryanum* the idea, developed by Blackman and Welsford (12) and Brown (16) for *Botrytis cinerea*, of the importance of mechanical penetration in the fungous invasion of plant tissues. While for *B. cinerea* mechanical pressure was found to be the main factor only in cuticle penetration, with *P. debaryanum* the penetration of the cell walls of all parts of the potato tuber was apparently largely dependent on mechanical puncturing by the hyphæ, only tubers with mechanically weak cell walls being susceptible to decay by the fungus. The extreme susceptibility to *P. debaryanum* and *Corticium vagum* of soft, thin-walled tissues and the resistance of older stems and root parts would fit in well with such a theory as to the method of wall penetration, as in the older tissues the thicker cell walls would obviously be a serious bar to the extension of a fungus dependent partly or en-

tirely on mechanical puncturing for its progress from cell to cell. Hartig (61, p. 147–150) shows a fungus which he does not name, but which is evidently a species of Fusarium, dissolving the young uncuticularized epidermis of pine seedlings; but he states that it can not so dissolve older epidermis. The increased protective value of the epidermis of older plants can only in part explain the immunity most of them develop against serious attack by damping-off organisms, as lesions already started or which may later develop from the infection of young roots are unable to extend into the older parts of the plants.

It may be mentioned here that the writer in a very preliminary test found strains of *Corticium vagum* and *Fusarium moniliforme* Sheldon which had been proved able to cause damping-off of pines also apparently able to destroy filter paper in inorganic salt solution, while *Pythium debaryanum* seemed not so able. Ruhland (116), on the other hand, found the strain of the "vermehrungspilz" (*Corticium vagum*) which he tested to be very weak in cellulose-destroying ability as compared with *Botrytis cinerea.*

DAMPING-OFF OF CONIFERS.

HISTORICAL.

While the losses from damping-off in seed beds of dicotyledonous tree species are occasionally serious and in the case of beech in Europe have required considerable study, they have been so far overshadowed in this country by the losses in coniferous seed beds that practically all the attention thus far, both as to etiology and measures of prevention, has been devoted to the disease in conifers.

The literature on the damping-off of conifers is considerable. A large part of it, because of the extensive early development of plant pathology and forest planting in Germany, has been written by Germans. A large portion of the German articles on it was either by foresters or by botanists in the day when most pathological work was of the reconnaissance type. Therefore, while the work of one of the best known of the parasites on coniferous seedlings was noticed in Europe as early as the eighteenth century (21, p. 252–253) most of the European data available are observational. The only fungi which were at all definitely connected with the disease on conifers seem to have been Fusarium (*Fusoma* spp.) and *Phytophthora fagi* (*P. omnivora* De Bary in part). The damping-off Rhizoctonia was described in Germany in 1858 and *Pythium debaryanum* in 1874; the fact that neither of these, important in coniferous seed beds in both the eastern and western United States, has ever been reported from conifers in Europe is perhaps the best evi-

dence of the relatively small amount of actual investigation carried on there on this disease in the nurseries. A number of references to the damping-off of conifers in the English horticultural and botanical literature yield even less definite information as to the causal fungi than do the German articles.

With the awakening of interest in reforestation in the United States between 15 and 20 years ago and the first efforts to grow pines in quantity for forestry purposes, attempts were made to determine the cause of the disease in this country and to develop direct-control methods. Duggar and Stewart (32) made what appears to be the first report of Rhizoctonia in connection with the damping-off of conifers. Spaulding (136, 137), in work begun in 1905, contributed much to our knowledge of the etiology of the damping-off of pine in this country, especially in relation to Fusarium, and originated the sulphuric-acid method of control. The writer in 1910 reported preliminary inoculations on conifers with both Rhizoctonia and *Pythium debaryanum* (62). The work of Gifford (46) and Hofmann (77) added to the information on the causal relation of *Fusarium* spp. and *P. debaryanum*, respectively. Hartley, Merrill, and Rhoads (68) have recently established the parasitism of a number of strains of the *Corticium vagum* type of Rhizoctonia on pine seedlings under inoculation conditions, have confirmed Spaulding's conclusions as to the parasitism of *Fusarium moniliforme* Sheldon, and have given preliminary data on other fungi. They consider *P. debaryanum* and *C. vagum* more important in pine seed beds than any single Fusarium species. Hartley and Hahn (69) have announced successful inoculations on pines with *P. debaryanum* and *Rheosporangium aphanidermatus* Edson, with less satisfactory evidence of the parasitism of *Phytophthora* sp. and a fungus tentatively referred to *Pythium artotrogus*. Hartley and Pierce (67) report the finding of *P. debaryanum* in *Tsuga mertensiana* and *Pseudotsuga taxifolia* as well as in the pines. In damped-off pine seedlings they find *P. debaryanum* more commonly than *C. vagum*, especially in beds which have received disinfectant treatments. Other considerations, however, keep them from concluding that the former is necessarily the more important of the two. Both of these latter papers and all of the reports of Pythium with the exception of Hofmann's are brief notes, presenting no evidence in support of the statements made.

DESCRIPTION.

The symptoms of damping-off in conifers have already been described in some detail (68). In the paper cited, injury due to excessive heat of the surface soil and injury caused by high wind, both of which may easily be confused with damping-off, are described and accompanied by colored illustrations both of different types of damp-

ing-off and of these nonparasitic troubles. The detailed descriptions will not be repeated here. A brief summary of the different types of disease recognized as included in damping-off follows:

(1) Germination loss: The radicles are killed very soon after the seeds sprout and before the seedlings can appear above ground. This is an important type, which can be caused probably by any of the organisms commonly capable of causing the better known types of trouble (61, 63, 68, 137).

(2) Normal damping-off (figs. 3, 4, and 5): The seedlings are killed by fungi invading either the root or hypocotyl after the seedling has appeared above the soil and while the stem is still dependent largely on the turgor of its cortical tissues for support. In sandy soils root infection is more common than hypocotyl infection, though the latter is the type most emphasized in the early horticultural descriptions. Büttner (26) some time ago recognized the frequence of

FIG. 3.—Normal type of damping-off of *Pinus ponderosa*. At the left is a damped-off seedling or root sprout of the southwestern ragweed (*Ambrosia psilostachya*). (Photographed by S. C. Bruner.)

root infections. Damping-off in beds out of doors is primarily in most cases a root rot, either of this type or of the types preceding and following.

(3) Late damping-off includes cases of the root-rot type occurring only after the seedling stems have started to become woody and the cortex has begun to shrivel. The damping-off parasites, or at least part of them, continue to kill seedlings by rotting their roots for some time after the stems become too woody to be decayed. The seedlings affected do not fall over till a considerable time after death. For convenience, all cases of this sort up to the purely arbitrary age of two months are classed as damping-off. However, in weather permitting of average speed of development the seedlings are usually able to resist attack before they reach this age. Seedlings at the marginal age between susceptibility and nonsusceptibility to killing infections are found often with the younger parts of their roots killed, but with the older portions apparently able to resist invasion by the fungus, recovery taking place by laterals. Dr. R. D. Rands and the writer in 1911 established the ability of seedlings from 43-day-old beds of *Pinus sylvestris*, *P. banksiana*, *P. nigra austriaca*, and *P. nigra poiretiana* to survive such infections, even when more than half of the root system has been destroyed, by transplanting such root-sick seedlings and

observing their continued growth (fig. 6). An article recently found (25) shows that Büttner had earlier made the same sort of demonstration of recovery of root-sick conifers. Observations on olive seedlings in 1916 showed cases of partially rotted roots which were recovering by sending out lateral root branches.

(4) Top damping: The cotyledons or upper part of the stem are invaded by the parasite, sometimes before the seedling breaks through the soil. The infection may or may not be fatal. A special case of this type, probably caused by a different parasite from those most commonly active, is that which in a publication above referred to was described and figured as "black-top" (68). It is

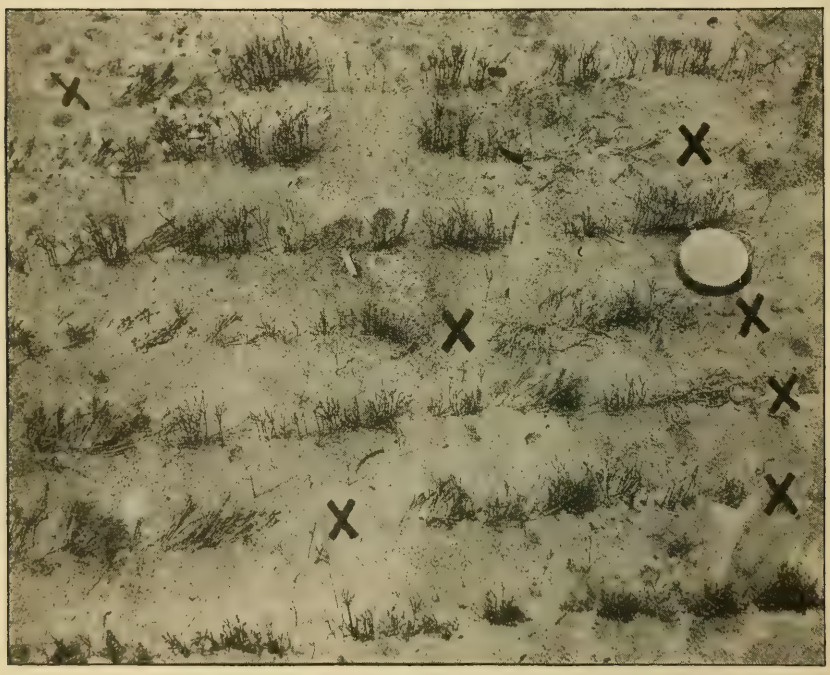


FIG. 4.—The beginning of an epidemic in drill-sown *Pinus banksiana*. Black crosses (X) indicate disease foci where the germinating seed were apparently killed and from which the disease is now spreading to adjacent seedlings. (Photographed by Dr. J. V. Hofmann.)

distinguished from ordinary top damping by the very dark color of the invaded tissues and its apparent dependence on some unusual set of climatic factors for its progress in the seedling after infection.

The killing of dormant seed by fungi is a matter of some practical interest in seed beds, and possibly still more so in forests, as it may help to explain the failure of certain conifers to reproduce except on mineral or certain other special soil types (68). With sugar beets *Pythium debaryanum* (100) is said to attack dormant seed as well as seeds which have sprouted. It is to be presumed that with conifers some of the damping-off fungi will be found to attack dormant as well as sprouting seed. This matter is now under investigation.

Something is already known about the seed fungi of herbaceous plants (76, 91), broad-leaved trees (79, 92), and juniper (95).

RELATIVE IMPORTANCE OF THE DIFFERENT TYPES.

Of the types of damping-off described in the foregoing pages the first two are ordinarily the most important. Late damping-off is rarely as serious as the normal type of damping-off. Top damping is only of importance in cases of excessive and unusual atmospheric moisture, so far as the writer's experience indicates. In the Middle West it has proved relatively insignificant. The three types which

FIG. 5.—Nearly complete destruction of the seedlings of *Pinus banksiana* at an unusually early age, at Garden City, Kans. (Photographed by Dr. J. V. Hofmann.)

occur after the seedlings appear above the soil surface can, of course, be evaluated by frequent counts during the damping-off season. This has apparently not yet been done by anyone. However, in experiments on damping-off control by soil disinfection, data have been obtained on comparative emergence (number of seedlings appearing above the soil surface) in treated and untreated plats and on the total parasitic losses after the seedlings appear which permit a certain amount of analysis of the losses due to damping-off parasites. The data from five nurseries bearing on this point are presented in Table I:

TABLE I.—*Relative importance of losses by damping-off before and after conifer seedlings emerge from the soil.*

Nursery and species.	Series.	Basis.			Loss in control plats.			
		Disinfectant.	Number of plats.		Emerged (viable seeds).			Ratio of col. 6 to col. 7.
			Treated.	Controls.	Before.	After.	Total.	
1	2	3	4	5	6	7	8	9
Bessey (Nebraska sand hills):					*P. ct.*	*P. ct.*	*P. ct.*	
Pinus banksiana	Average of 9	Sulphuric acid	(a)	(b)	37.8	c27.2	65.0	c1.39
Pinus ponderosa	Average of 2	do	6	8	28.1	27.3	55.4	1.03
Pinus resinosa	Average of 3	do	4	7	29.4	54.1	83.5	.54
Garden City (southwestern Kansas):								
Pinus austriaca	Average of 2	Copper sulphate.	4	3	69.0	27.5	96.5	2.52
Pinus banksiana	do	Zinc chlorid	3	2	80.7	12.0	92.7	6.72
Pinus ponderosa	Average of 7	Copper sulphate.	17	29	15.3	30.9	46.2	.49
Cass Lake (northern Minnesota):								
Pinus resinosa	No. 1051	Formaldehyde	6	3	3.8	37.2	41.0	.10
	No. 1052	do	6	3	25.7	36.2	61.9	.71
	No. 1053	Zinc chlorid	4	4	5.7	26.2	31.9	.22
	No. 1054	do	4	3	7.4	43.6	5.1	.18
	Nos. 1057 and 1061.	Heat	4	2	4.9	16.9	21.8	.29
East Tawas (Michigan):								
Pinus resinosa	1073	Formaldehyde	6	3	5.9	45.3	51.2	.13
	1074	Sulphuric acid	2	7	58.2	18.0	76.2	3.25
Fort Bayard (New Mexico):								
Pinus ponderosa	Nos. 791 and 792.	Formaldehyde	7	8	12.6	36.1	48.7	.35
	Nos. 891 and 892.	Sulphuric acid	8	6	14.5	18.6	33.1	.78

a Area counted, 122 square feet. b Area counted, 78 square feet.
c In *Pinus banksiana* at the Bessey Nursery, the loss after emergence is slightly low and the ratio slightly high, because of the closing of counts on a few of the series before damping-off was entirely over.

The procedure was to average the number of seedlings which emerged in the control plats in each series and subtract this number from the average number emerging (that is, appearing above the soil surface) in the treated plats in the same series. The treated plats chosen were the ones which allowed the averaging of the greatest number of plats treated with the same disinfectant. Only those plats were taken in which there was no evidence of injury to the seed or seedlings by the disinfectant and in which the amount of normal damping-off during the first few days after emergence was so slight as to indicate satisfactory initial control of the parasites by the treatment. In such plats it was assumed that the germination loss was unimportant, and the average number of seedlings appearing on them was taken as representing the number of viable seeds per plat. The difference between this emergence figure and the average emergence in the controls was taken as indicating the extent of parasitic loss before the seedlings appeared, including any destruction of dormant seed by parasites which may have occurred as well as the killing of germinating seed. Both this figure and the number

of seedlings which succumbed to damping-off after emergence were reduced to a percentage based on the indicated number of viable seeds, and they are directly compared in columns 6 and 7 of Table I. At three of the nurseries the data of the same species of pine and with the same treatment were averaged.

The data in Table I do not indicate any regularity either in the extent of loss before emergence, the loss after emergence, or in the ratio between these two values. For obvious reasons, no regularity is to be expected in any of these items. The table is of some interest, however, in confirming the evidence of the inoculation experiments, of observation of sprouting seed dug up in the beds, and of the partial or complete failure of emergence at the centers of large damping-off foci (figs. 4, 7, and 8) that the work of parasites before the seedlings appear may in some cases be of considerable importance. It is obviously impossible to make any general quantitative statement of the seriousness of such loss, in view of the variation in its extent at different times and places and of the inaccuracy of any computations based on the relative emergence of hosts as irregular in their germination as the conifers are known to be. The case is complicated in addition by the fact that, despite careful avoidance of treated plats known to have suffered chemical injury, it is probable that a few seedlings were killed before emergence by the disinfectants used in some of the

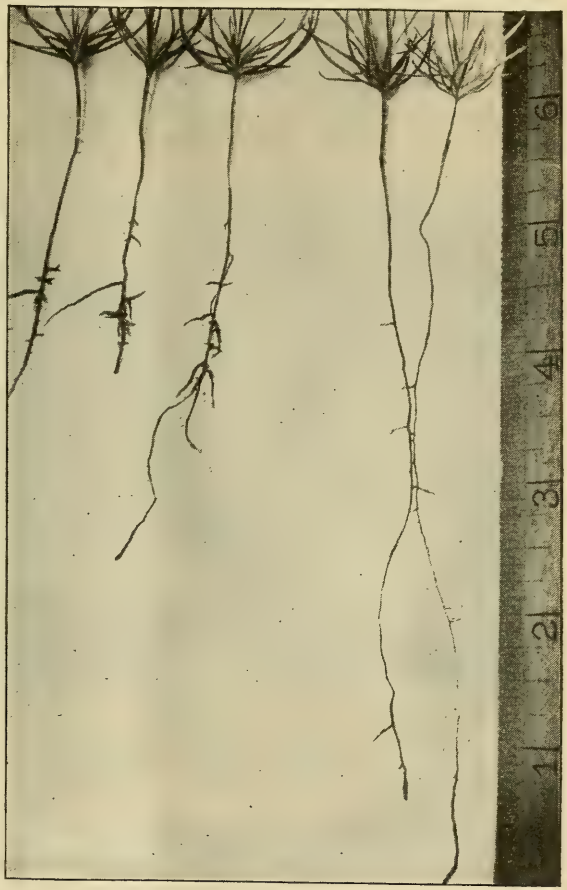


FIG. 6.—Root sickness in *Pinus nigra poiretiana*. The two seedlings at the right are healthy. The three at the left have had their taproots decayed to within 1½ inches of the soil surface. All are putting out lateral roots from the lowermost sound point. Similarly injured seedlings when transplanted lived and made satisfactory growth.

cases. It may furthermore be that in other cases the disinfectant had a stimulating effect, resulting in better germination in the treated plats, entirely aside from that resulting from parasite control. The number of disinfectant methods which concurred in giving apparent increases in germination, however, makes it seem reasonably certain that no great part of the increase was due to this stimulation.

In addition to the different disinfectants shown in the table, mercuric chlorid, heat, hydrochloric acid, nitric acid, and ammonia all apparently resulted in approximately the same increases of germination in tests at the Bessey Nursery as the sulphuric acid which was used as the standard for comparison in most of the series. Relative emergence in treated and untreated plats, as well as damping-off

FIG. 7.—A clean-killed area in a bed of *Pinus ponderosa,* caused by *Corticium vagum.* Inside a 12-inch circle at the center of this "patch" no seedlings appeared. It will be noted that the weeds as well as the pines have been killed with the exception of *Salsola tragus.*

loss after the seedlings appeared, was determined at two nurseries in addition to those given in the table. The results at these nurseries in general confirmed those at the five nurseries covered by the table in showing lower emergence in the controls. Although it is impossible to draw positive conclusions, some idea of the seriousness of losses before the appearance of the seedlings above ground can be obtained by studying the data in Table I. The fact that such losses appear considerable, sometimes exceeding the losses from the damping-off that occurs after emergence, is believed to explain the common failure to secure satisfactory results from control measures taken after the seedlings have come up and the disease has become noticeable. It is somewhat interesting to note that the data in the

table tend to confirm field observations that, as compared with other species, *Pinus resinosa* is more susceptible to the later forms of damping-off than to germination loss.

Further indication that the killing of germinating seed before emergence may be important enough to help explain cases of poor germination is obtained by an entirely different method, as follows: At the Wind River Experiment Station of the United States Forest Service counts of the seedlings emerging and of those which later died were made on a number of untreated plats by forest officers, who kindly permitted the writer to use the data obtained. The counts were made separately on 10 plats each of noble fir (*Abies nobilis*) and silver fir (*Abies concolor*). The plats of each species had been sown with equal quantities of seed. It appeared on inspection of the figures that the plats which showed the poorest emer-

FIG. 8.—The area shown in figure 7 after the bed had been weeded and damping-off had practically ceased. (Photographed by S. C. Bruner.)

gence were also the ones which suffered the most subsequent loss. The coefficient of correlation between the number of seedlings emerging and the percentage of subsequent loss in the same plats was found to be -0.49 ± 0.16 for the noble fir, and -0.50 ± 0.16 for the silver fir, an average of -0.49 ± 0.11 for the two species, confirming the conclusion drawn from inspection of the figures. In other words, poor emergence and heavy subsequent loss were in general associated. The simplest explanation of this association appears to be to suppose that both poor emergence and subsequent loss were largely due to the same cause, namely, the damping-off parasites. Another possible explanation of the correlation would be to neglect parasites as important causes of the poor emergence in certain plats and to suppose that the higher subsequent loss in such plats was due to heat injury, the less dense stands affording less shade to the bases of the seedlings composing it. As damping-off is in general so much more important than heat injury as a cause of death after emergence and the difference in the degrees of shade between the plats with the denser

and the plats with the thinner stands must have been very slight, this latter explanation has not much to support it. The data are believed to constitute further evidence of the importance of parasites in decreasing the percentage of emergence in coniferous seed beds. That the effect of parasites on emergence should have been large enough in this case to make itself apparent on the face of the figures, despite the variations due to other sources, is especially interesting in view of the fact that the losses after emergence in these plats were not high.

ECONOMIC IMPORTANCE OF DAMPING-OFF.

The importance of damping-off in coniferous nurseries in Europe is indicated by frequent reference to the disease in the literature. Büttner (25, 26) states that whole beds are frequently destroyed by it. Baudisch (9) speaks of the death of entire stands in many nurseries as the result of damping-off. In the United States Spaulding (137) considers damping-off a serious obstacle in forestation operations. Clinton (28, p. 348–349) reports serious damage to conifers in New England nurseries. The writer has found the disease especially prevalent in nurseries in Nebraska and Kansas, a somewhat unexpected situation in view of the relatively dry conditions prevailing there. A correspondent has reported heavy loss in seed beds in Texas.

The economic importance of the disease in conifers is due in part to the rather heavy average losses experienced at many nurseries and in part to the irregular character of the losses. In one season losses may be negligible, while the next season the beds of certain species may be practically wiped out. Even without this element of uncertainty the losses experienced are expensive, because of the high cost of coniferous seed. The seed of some species costs from $3 to $5 a pound and seldom shows a germination of more than 60 per cent under nursery conditions. A loss of half of this 60 per cent from parasites, both before and after the seedlings break through the soil, is therefore a matter which deserves attention. The figures in column 8 of Table I, obtained by adding together those in columns 6 and 7, show that the loss is frequently higher than this. At the nurseries at which control experiments have been conducted, the percentage of the seedlings in untreated beds which have been found by actual count damped-off after emergence is frequently more than 50 per cent, in addition to the considerable but less accurately determinable loss indicated by the foregoing data as being caused by the parasites before the seedlings appear.

It has been suggested by foresters and others that the net economic damage from damping-off is not as great as is indicated by the loss of seed and seedlings which it may cause. The argument is ad-

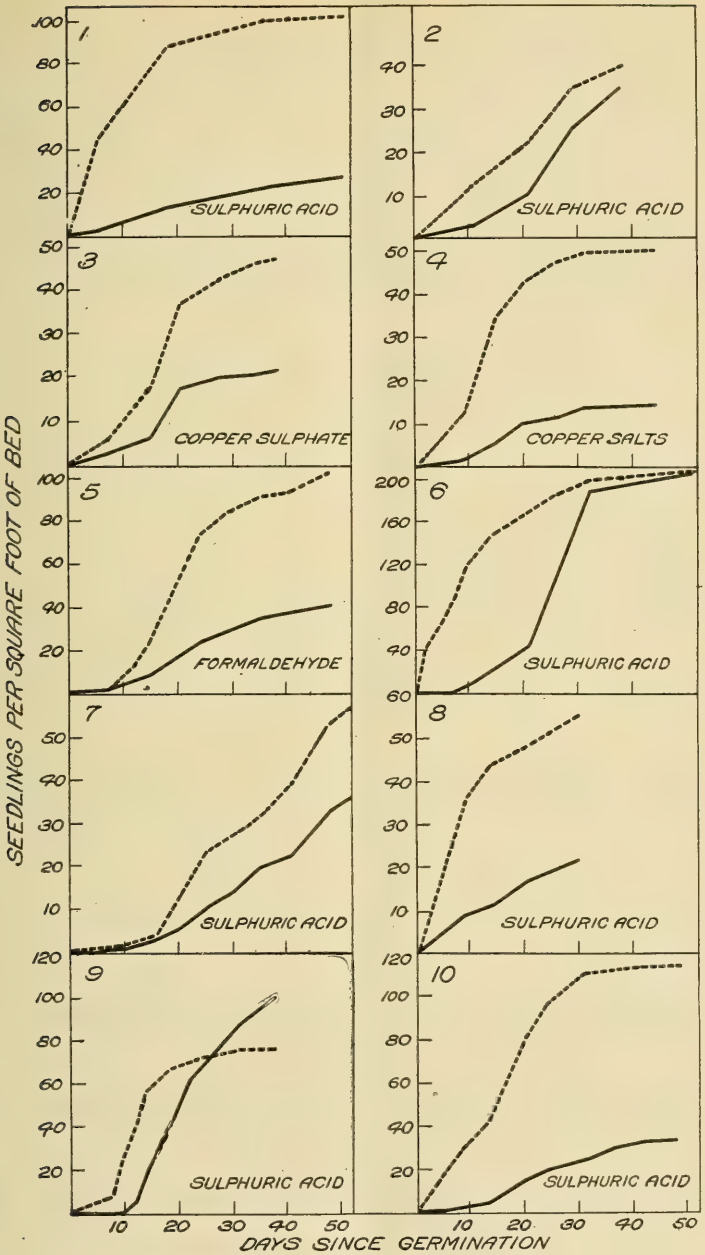


FIG. 9.—Diagram showing the progress of damping-off in treated plats (solid line) as compared with untreated plats (broken line). Graphs 1 to 4 represent *Pinus ponderosa;* graphs 5 to 8, *P. resinosa;* graph 9, *P. banksiana;* and graph 10, plats each of which was half *P. nigra poiretiana* and half *P. sylvestris.* Nurseries in Kansas, Nebraska, Minnesota, and Michigan are represented. The relatively high total number damped-off in the treated plats shown in two of the graphs is due to the fact that a large proportion of the seedlings in the untreated plats had been killed before they appeared above the soil surface. In both the cases in which the absolute number of seedlings killed was as great in the treated plats as in the controls, the percentage of the seedlings killed was nevertheless lower and the survival more than twice as good as in the controls.

vanced that damping-off may be a valuable selective agent in nursery-grown stock for forest planting, eliminating the weaker individuals and thus insuring the vigor of the trees which go into the forest plantation. This is a possibility which must be considered. It is by no means certain, however, that escape from damping-off is correlated with permanently superior vigor. It is believed that temperature, moisture, and other environmental factors, which as yet are very imperfectly analyzed, together with the age of the seedlings and the presence or absence of virulent strains of the parasites, are much more important factors than inherent differences in individual resistance in determining whether or not seedlings are destroyed. Evidence from inoculation experiments and from field observation, supported by data of the sort presented in Table I, indicate that damping-off ordinarily does a considerable part of its damage by killing the sprouting seed before emergence from the soil, while the graphs in figure 9 show that of the loss which occurs after emergence in untreated beds a large part occurs very early in the life of the seedlings. Observation of the clean sweeps which the disease commonly makes in the immediate neighborhood of infection foci (figs. 3, 4, and 5) indicates that either before or just after the seedlings break through the soil none of them have any considerable resistance to the really virulent strains of the parasites, which are believed to be the ones responsible for the major share of the damping-off.

Even if there should be found to be an appreciable selective value in damping-off, this would not be a valid argument against control by seed-bed disinfection for the following reason: The graphs showing the course of damping-off in treated plats in figure 9, together with the decided differences in germination between treated and untreated plats, indicate that the very early damping-off is more completely controlled by disinfectants than the later damping-off. This early damping-off which the treatments so largely prevent is the part of the loss which has the least possibility of selective value. The later damping-off is rarely controlled at all thoroughly by disinfectants. As shown by the graphs, it is often even heavier on the treated than on the untreated soil. It is the part of the loss which is most likely to have selective effect. At this stage beds are not taken clean, as earlier; only seedlings which are below normal resistance succumb. The damping-off in disinfected beds seems therefore at least as likely to have true selective value as that which occurs in untreated beds.

The only way in which the effect of damping-off as a selective agent can be positively determined will be to compare through several subsequent years the growth rate, or survival after transplanting, of trees from beds which suffer seriously from damping-off with the growth of trees from the same lot of seed in seed beds in

which the disease is either accidentally absent or is artifically controlled. Such an experiment is within the silvical rather than the pathological investigative field. If it be found that there is some selective value in the action of the disease and that it is greater in untreated than in treated beds, it would still seem that a much more desirable and dependable selection could be obtained by discarding weak plants at the time of transplanting than by letting damping-off run uncontrolled in the seed beds. Damping-off is sometimes negligible and sometimes destroys practically all the seedlings in a given area, in neither of which cases can it have any material selective value.

RELATIVE SUSCEPTIBILITY OF DIFFERENT CONIFERS.

Büttner (25) writing of European conditions, states that exotic conifers are especially subject to damping-off. He includes fir, spruce, pines, larches, and cypress in this statement. He mentions the same subject in a later paper (26). Neger and Büttner (94) give a long list of different species of conifers from various parts of the world with statements as to their susceptibility to damping-off. Beissner (11, p. 656–657), Neger (93), Clinton (28), Bates and Pierce (7), Boerker (13), and Tillotson (139, p. 69) have all given information on the susceptibility of different conifers. The data reported by Tillotson are drawn from reports by various officers of the United States Forest Service which he has compiled. While it is probable that the nurserymen who are responsible for most of his records have not observed the disease as closely as Neger and Büttner, the fact that their observations are mostly based on repeated seasons' work with large-scale seed beds of the species they report on makes their observations in some respects more reliable than the other published data. Neger and Büttner presumably worked in most cases with small beds of the various conifers on which they report, and the variations which they attribute to differences in specific resistance might easily in such case be largely due to accidental variation. The error which nurserymen are most likely to make in their notes on susceptibility is to underestimate the loss, especially for the small-seeded species. The seedlings of small-seeded conifers decay and shrivel so quickly after they fall that in taking notes at any one time only a small proportion of the total loss is visible. Frequent counts of dead seedlings are the only way by which the loss after germination in such species can be properly appreciated.

The data given by the authors mentioned in the foregoing paragraph, together with unpublished data obtained by personal observation or from commercial and other nurserymen in the United States, are summarized in Table II, the source of each report being shown by letters signifying the authority. The unpublished data on two

nurseries in Illinois and Minnesota were obtained from the nurserymen by Mr. R. G. Pierce and are indicated by the initial "P." Information obtained directly from the nurserymen by the writer is indicated by "N." For nurseries where the statements are based on the writer's personal observation rather than on the authority of the nurserymen, his own initial ("H") is given. Most of the writer's own estimates of relative susceptibility are based on a comparison of detailed counts of the damped-off seedlings in a large number of untreated plats at different times, as well as on observation. The nurseries on which Tillotson reported were all west of the Missouri River, most of them being in the mountain region. The reports indicated by "H" and "N" were mostly from nurseries east of the Rocky Mountains. In cases in which the data permit it, the species are classified as most susceptible, intermediate, least susceptible, or immune. In a number of cases, however, it is only possible to classify them as "more" or "less" susceptible.

TABLE II.—*Relative susceptibility to damping-off of different conifer species.*

[Figures in parentheses in this table indicate the number of nurseries from which the susceptibility noted has been reported by the observer to whom the preceding letter refers.]

Host species.[a]	Reports of relative susceptibility.[b]					
	Not susceptible.	Least susceptible.	Less than average.	Intermediate.	More susceptible than the average.	Most susceptible.
Pinaceæ (Abietoideæ):						
Abies spp		(c)				
Abies balsamea		Nb				
Abies cephalonica				Nb		
Abies concolor						Bu, Nb.
Abies nobilis			T			Nb.
Abies nordmanniana				Nb		
Abies picea (A. pectinata)				Nb		
Abies sacchalinensis (?)				Nb		
Abies sibirica		Nb				
Abies veitchii						Nb.
Cedrus deodara			T			
Larix europæa				Nb	N (2)	
Larix leptolepis						Nb.
Larix occidentalis			T		T	
Picea ajanensis			Ne	Nb		
Picea canadensis		Nb		P	N	
Picea engelmanni			T (2)		H, N, Ne, T.	Nb.
Picea excelsa	P	Nb	H, Bu		Ne, N	
Picea omorika			Ne	Nb		
Picea orientalis			Ne	Nb		
Picea pungens			N (2)	H, P	Ne	N (2), Nb.
Picea sitchensis					Ne	Nb.
Pinus aristata		Nb				
Pinus attenuata					N	
Pinus banksiana		Nb	N	P	B, P, H (2), T.	B., H.
Pinus contorta	T	Nb	T			
Pinus edulis	T					

[a] Host names for American species follow the usage in the publications and a later verbal communication of Mr. George B. Sudworth, of the United States Forest Service. For exotic species the Standard Cyclopedia of Horticulture, New York, 1916, edited by L. H. Bailey, is taken as the standard. The classification follows Saxton (118).

[b] Symbols signifying the authority for the report: B=Boerker (13), Bu=Büttner (25, 26), Bp=Bates and Pierce (7), C=Clinton (28), H=Writer's estimate, N=Nurserymen's estimate (obtained by the writer), Nb=Neger and Büttner (94), Ne=Neger (93), P=Nurserymen's estimate (obtained by Pierce), T=Forest officers' estimate (compiled by Tillotson, 139).

[c] Susceptibility to *Phytophthora fagi*.

TABLE II.—*Relative susceptibility to damping-off of different conifer species*—Continued.

Host species.	Reports of relative susceptibility.					
	Not susceptible.	Least susceptible.	Less than average.	Intermediate.	More susceptible than the average.	Most susceptible.
Pinaceæ (Abietoideæ)—Continued.						
Pinus excelsa		Nb				
Pinus flexilis		N				
Pinus jeffreyi			T		T (2)	
Pinus lambertiana					T	
Pinus montana mughus				P		
Pinus monticola	T		T		T	
Pinus nigra austriaca (Austrian pine)		Nb	N, T (3)		Bp, N, T	
Pinus nigra poiretiana (Corsican pine)	Bp			H		
Pinus palustris				B		
Pinus peuce		Nb				
Pinus ponderosa (type not specified)	T (3)	P	Bp, N (4), T (6).	Nb	T (4)	
Pinus ponderosa (Eastern Rocky Mountain type)			H (4)		B	
Pinus ponderosa (Pacific coast type)			B			
Pinus resinosa			N (3)		Bp, H, T	B, H.
Pinus rigida			P		N	
Pinus strobus	P		B, H, N	N	C, N, T	
Pinus sylvestris			T (2)	H, P	Bp, T (3)	N.
Pinus taeda		B				
Pinus thunbergii		Nb				
Pseudotsuga taxifolia (type not specified)			N (3) T (3)	H	N, T (5)	
Pseudotsuga taxifolia (Colorado type)		Nb			B	
Pseudotsuga taxifolia (Northwestern type)		B		Nb		
Tsuga canadensis				Nb, P	Bu	
Number of reports	9	17	51	23	48	15
Percentage of total	6	10	31	14	29	9
Sciadopitoideæ:						
Sciadopitys verticillata						Nb.
Cupressaceæ (Cupressoideæ):						
Chamaecyparis lawsoniana		Nb	T		Bu	
Chamaecyparis pisifera		Nb				
Cryptomeria japonica				Nb		
Cupressus spp		Nb				
Cupressus arizonica	N					
Juniperus communis	Nb			P		
Juniperus monosperma	N					
Juniperus pachyphloea	T					
Juniperus virginiana	H, P	Nb				
Libocedrus decurrens	T	Nb	T			
Taxodium distichum		Nb				
Thuja occidentalis	P	Nb				
Thuja orientalis	P			Nb		
Thuja plicata				Nb		
Number of reports	9	7	2	4	1	0
Percentage of total	39	30	9	17	4	0
Sequoideæ:						
Sequoia spp					B	
Sequoia washingtoniana					T	
Taxaceæ:						
Taxus cuspidata	P					

The fact most evident in Table II is the extreme variation between reports, not only on closely related species but even on the same species. While it is, of course, possible that the obvious lack of a definite basis and method of comparison in most of the reports is responsible for most of this variation, it seems to the writer more probable that different species do actually vary in their relative susceptibility to damping-off in different localities. In the first place,

the conditions which might increase resistance of one host might very easily decrease its resistance for a host with different environmental requirements. To illustrate by an extreme example, the piñon (*Pinus edulis*) of the arid or semiarid region might remain resistant in soils in which *Picea engelmanni* of the high mountain-stream bottoms or *Picea mariana* of the northern swamps might be low in vigor and easily attacked. In the second place, it is to be expected that species with a certain order of relative susceptibility to the parasites which predominate at one nursery may exhibit a very different order of susceptibility to the different combination of parasites which might be prevalent in another locality.

The only individual species on which there are a sufficient number of reports and a sufficient agreement between the reports are the two common western spruces, *Picea pungens* and *P. engelmanni*, which (at least as compared with *Picea excelsa*) seem rather susceptible, and *Pinus ponderosa*, which (as compared with most of the other species of the Abietoideæ) is to be regarded as generally more resistant than the average. Within each of the larger genera of this group it seems evident that susceptibility is extremely varied and that no statement as to the relative susceptibility of the genera themselves can therefore be made. The only group generalization that is perhaps permissible is derived from the consideration of the Cupressoideæ. In this group, out of 23 reports, 16 are in the "not susceptible" or "least susceptible" columns and only one indicates more than intermediate susceptibility. Of 163 reports pertaining to the Abietoideæ, only 26 place them in the "not susceptible" or "least susceptible" columns and 63 in the classes of more than intermediate susceptibility. The general feeling among nurserymen seems to be that serious damping-off need not be feared among the cedars and their relatives. The data at hand tend to justify this confidence.

CONTROL OF DAMPING-OFF.

Early efforts to prevent damping-off were chiefly directed to the avoidance of excessive moisture in either the air or soil. A means to this end, which has been observed more or less by nurserymen for many years, both in the United States and elsewhere, is the application of small quantities of dry sand to the seed beds after the disease becomes noticeable (18, p. 166; 83). This is sometimes applied hot (101, p. 43–44; 145), though even this procedure does not result in very great advantage. Surfacing with hot sand can not always be counted on to give any measurable advantage over untreated beds (67, p. 3). The use of sand (25) or sterile subsoil (101) instead of ordinary soil in covering seed at the time of sowing has been advised. Johnson (82) did not secure satisfactory results with sand in tobacco

beds. Making the upper part of the bed to a depth of several inches of recently dug subsoil appeared effective in a single test by Spaulding (137) and at four nurseries by cooperators of the writer in later tests, the results of which will be published elsewhere. The procedure is unfortunately rather expensive in large-scale work and under some conditions at least undesirable because of the poor subsequent growth on such soil. Excessive vegetable matter (45), imperfectly rotted manure (67), or green manures recently plowed under (43) have all been advised against as likely to favor the disease. The experience reported with conifers (67, 139) indicates that damping-off can be to a certain extent decreased by broadcast sowing as compared with sowing in drills. The usual recommendation of thin sowing to avoid the seed-bed disease of other plants has also been made for conifers (67). Transplanting healthy seedlings from infected beds into new soil is recommended as a means of saving them from attack (11, 145). The writer's tests of transplanting at a Nebraska nursery gave no promise of economic value as a control method, although he is informed that it was successfully employed in a nursery in New Mexico. The time of sowing appears to have a relation to the amount of disease at some nurseries, but conditions in this regard evidently differ in different localities, so that the best time to sow from the standpoint of avoiding damping-off must be determined separately by repeated tests at each nursery. For example, observations both by the nurserymen and the writer during several seasons at the Bessey Nursery, in Nebraska, indicate that fall sowing is an excellent means of decreasing loss from damping-off in at least one pine species, and Retan (110) reports the same thing for a nursery in Pennsylvania, while at two Kansas nurseries and at nurseries mentioned by Tillotson (139) fall-sown beds suffer more than those sown in the spring.

Treatment of the seed with mercuric chlorid (25) or with copper sulphate (122) has been recommended. While it has been demonstrated (38) that a proper heat treatment of the seed will greatly decrease the damping-off in sugar-beet seedlings, this is explained by the fact that one of the most important parasites of the sugar beet is systemic and often present in the seed. There is no reason to believe that seed-carried infection is of any importance in coniferous seed beds. The only advantage that could reasonably be expected from a seed treatment of conifers would be that which would come from the prevention of seed decay in the soil before germination starts, and this protection could be expected to be effective only if a relatively insoluble disinfectant, such as Bordeaux mixture, was used.

Soil treatment is the most direct and probably the most profitable method of attack on the disease. It is especially easy, for tobacco

seedlings (82) as well as for pines, to prevent by soil disinfection losses before the seedlings appear above the ground. Heat disinfection of seed beds has been frequently mentioned. Burning wood or litter on the surface of the beds before sowing, said by Gilbert (47, p. 36) to be a common procedure in preparing tobacco seed beds both in Italy and in parts of this country, has been recommended for coniferous seed beds by Büttner (25). The disadvantageous results sometimes noticed following the application of wood ashes to pine seed beds may prove an objection to this type of treatment in some of the nurseries. At a Nebraska nursery (67) moist heat proved only partly satisfactory, unavoidable reinfection having serious results. Steam disinfection, using the inverted-pan method commonly advocated for tobacco seedlings (10, 47, 81), has been reported by Scott (123) as successful at a nursery in Kansas. Gifford (46) found steaming with the inverted pan only partly satisfactory. It is not believed that it is likely to pay to install the necessary apparatus for steam disinfection at nurseries in nonagricultural districts where steam tractors are not available for temporary use. The hot-water soil treatment as used by Byars and Gilbert (27) is probably worth a trial at any nursery where damping-off is serious and fuel cheap. It may be that in some localities where steam or hot-water treatment of the soil is not sufficiently effective, its efficiency can be increased by reinoculating the soil immediately after treatment with saprophytic molds and bacteria to provide maximum competition for parasites which come in from the outside. Tests of this procedure will be described later in the present bulletin. The value of charcoal has been emphasized by Retan (109, 110).

Chemical disinfection of the soil has also been employed. Sulphur has long been in use as a soil treatment against the damping-off of various plants (45, 111) in addition to its use in combating potato scab and onion smut. It was tested on conifers by Spaulding (136, 137) in the form of light surface applications to the beds after germination, but without decisive result. In later cooperative tests powdered sulphur raked into the soil before the sowing of the seed failed to indicate any large measure of value. Very finely divided forms of sulphur in various amounts and times of application are probably worth some further test.

Möller (90) and Sherbakoff (128) have reported the successful use of copper sulphate in combating attacks of Corticium on dicotyledons. In Johnson's experiments on tobacco seedlings (82, table 3) copper salts and Bordeaux mixture were the only chemicals for which any value was indicated. Sherbakoff apparently used copper sulphate and other strong disinfectants chiefly to stop the extension of vigorously spreading damping-off foci by local treatment rather than as a general treatment for use over the beds. Such treatment

would presumably kill all seedlings on the area treated, but would, of course, be of considerable value in stopping at the outset such mycelia as those which caused the damped-off area in figure 7. The procedure would be of practical value only in cases in which damping-off was chiefly limited to a few large patches of this sort, a rather rare condition in conifers.

Copper sulphate solutions have been used on pine seed beds at the time of sowing with considerable success at some nurseries (65, 67). Except in a nursery in which the soil contained carbonates, it has proved rather difficult to prevent injury to the pines. The trial of some such combination of copper sulphate and lime as was used by Spaulding (136) on the surface of pine beds before sowing, which apparently prevented the damping-off of lettuce in some unpublished pot experiments of Mr. J. F. Breazeale, is considered desirable. Treating seed beds with ordinary Bordeaux mixture has also been recommended. Horne (78) secured especially good results against *Corticium vagum* in tobacco seed beds by heavy applications of Bordeaux mixture, and Schramm (122) and Clinton (28) have obtained indications of its value as a spray in preventing the damping-off of conifers. It is probably worth further tests in various amounts of application. In tests conducted by the writer in 1912 and still unpublished, some advantage was indicated for Bordeaux mixture as a surface treatment after soil disinfection with acid. Zinc chlorid as a soil disinfectant has also been found valuable in a number of cases (65, 67), but it is more expensive and apparently less dependable than copper sulphate.

Formaldehyde and sulphuric acid have been tested more frequently than other disinfectants. The use of sulphuric acid on coniferous seed beds was originated by Spaulding (136). The first intensive experiments with this acid were reported by the writer (63). The first experiments with formaldehyde on conifers seem to have been in the early greenhouse tests of Spaulding (137), repeated in forest nurseries in 1907 by Jones (83) and Spaulding (136). Most of the experiments with these two substances have already been summarized (67). A report not mentioned in this summary is that of Schaaf (119, p. 88), who obtained favorable results with the acid. The great trouble with formaldehyde is its tendency to kill dormant seed. The length of time which must be allowed to elapse between treatment and sowing in order to avoid this killing varies with conditions. Formaldehyde is more expensive than acid and seems on the whole to have been less effective in disease control. Acid, on the other hand (applied just after the seed is sown, which is found to be the best time), on a few soils has caused injury to radicles, which it was at first thought could be prevented only by very frequent watering during the germination period; while in a few cases, when cold

weather resulted in a long germination period, it has killed or inhibited the germination of some of the dormant seed. All injury can be prevented by treatment a few days before sowing, followed by the addition of lime just before sowing, but lime used in this way has apparently destroyed a considerable part of the value of the acid treatment against the disease. Further consideration of the data on which earlier papers (63, 67) were based indicates that the apparent need for frequent watering during the germination period, which was required at a few of the nurseries where the first tests of acid treatment were made, as well as practically all of the germination reduction, was due to the use of unnecessarily large applications of acid and that the trouble can be eliminated by determining by test the minimum quantity of acid which will be reasonably effective in each locality. If this can be done it should establish the acid treatment as the most profitable for general use of any of the methods of damping-off control which have so far been extensively tested.

In view of the various parasites which may cause damping-off at different times and places and which vary greatly both in their means of dissemination and in their physiological qualities, it is not believed that any single disinfectant will be found entirely satisfactory at all nurseries. It is also unfortunately true that no one strength of treatment can be recommended for all nurseries. The quantity of acid to be used at any specified nursery will have to be determined by test at that nursery. A single test, no matter how well conducted, is not sufficient to serve as a basis for conclusions. However, a number of small-scale tests, made at different times and in different parts of the seed-bed area, should determine the best treatment for any particular nursery with a reasonable degree of certainty and with very little work. If the plats are equal in size and receive equal quantities of seed, all the nurseryman needs to do to determine the value of the treatments is to count the number of living seedlings on the different plats at the end of the season. The decrease in the number of weeds as a result of the use of acid is itself sufficient at a number of nurseries to pay the entire cost of the treatment. Detailed methods of application have already been published (67). The differing proportions of acid between which the best treatment will ordinarily be found to lie are 2 and 7 c. c. (one-sixteenth and one-fourth of a fluid ounce) of the concentrated commercial acid per square foot of seed bed, applied just after the seed is sown and covered. It should be dissolved in 500 to 1,000 c. c. (1 to 2 pints) of water per square foot of bed before applying. The drier the soil before treatment, the more water should be used in dissolving the acid.

No treatment applied after germination begins can have the maximum value in controlling the disease, because the damping-off para-

sites frequently, if not usually, do part of their work before the seedlings appear above the soil. Furthermore, any treatment at all effective against the disease is almost certain to hurt the seedlings if applied after the seed starts to sprout.

Both the acid and copper-sulphate treatments which have been found useful in pine seed beds are of very doubtful value for most hosts other than conifers, as the angiosperms on which observations have so far been made are too easily injured by the disinfectants. The weeds in the nurseries have been injured or entirely kept from appearing by treatments which caused no injury to the pines.

CAUSAL FUNGI.

CORTICIUM VAGUM.

Occurrence and parasitism.—In a recent publication (68) *Corticium vagum* B. and C. (*C. vagum solani* Burt, *Hypochnus solani* Pril. et Del., the common damping-off Rhizoctonia) has been reported on a number of conifers. Inoculation, reisolation, and reinoculation on pine have established its parisitism on this host beyond a reasonable doubt, though in these inoculations, as in most, if not all, the work which has been done with the fungus on angiospermous hosts, the cultures employed have been from plantings of diseased tissue instead of from single spores. The inoculation experiments have confirmed the field observations indicating that this fungus is fully as able to cause loss by destroying germinating seed below the soil surface as to cause damping-off of the better known type after the seedlings appear above the soil surface.

An extensive list of angiosperms on which the fungus has been reported is given by Peltier (98). Cross-inoculations between the pines (68), on the one hand, and potato (40) and sugar beet (38) have shown the same strains to be parasitic on both conifers and angiosperms and established the physiological as well as the morphological identity of the fungus attacking pines with the common *Corticium vagum.* Now that Duggar (34) has offered strong, though not yet entirely conclusive, evidence of the identity of *C. vagum* with the European "vermehrungspilz" (the *Moniliopsis aderholdii* of Ruhland; 115) it is to be presumed that it is a cause of damping-off of conifers in Europe as well as in America, though no reports of it on conifers have been so far encountered in European literature. The Rhizoctonia reported by Somerville (132) on *Pinus sylvestris* and the *Rhizoctonia strobi* described by Scholz (121) as killing young *Pinus strobus* were both on trees more than 4 years old, so that they had no relation to damping-off. Furthermore, the first of these was apparently the old *Rhizoctonia violacea*, now known as *R. crocorum* (*R. medacaginis*), a fungus entirely distinct from *Corticium vagum*, probably belong-

ing to an altogether different group of fungi and not known to cause damping-off of any host. *Rhizoctonia strobi* is not sufficiently described to allow determination of its identity.

Variations in virulence.—In the inoculations earlier reported on conifers, different strains of *Corticium vagum* were said to vary greatly in virulence (68). Further examination of the data on which this statement was based yields confirmatory evidence. Part of this evidence is shown graphically in figures 1, 2, and 10. The experiments on which these graphs were based involved at the time of seed sowing the addition to the soil of apparently pure cultures of *C. vagum.* Throughout each experiment the different units received

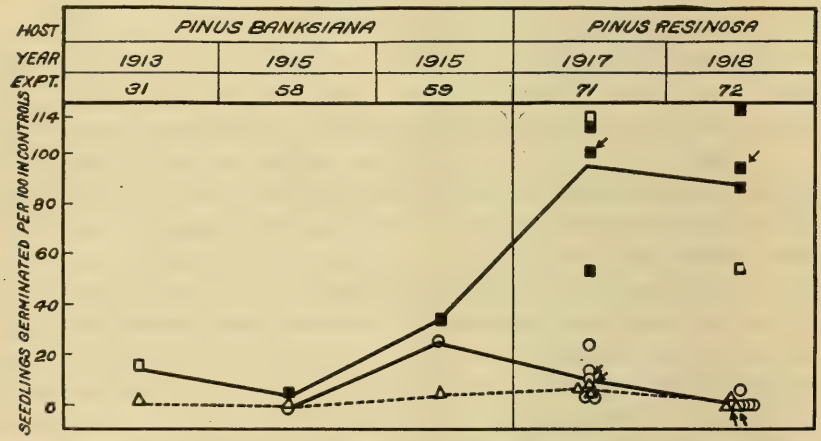


FIG. 10.—Diagram showing the relative activity of different strains of *Corticium vagum,* as indicated by the number of seedlings appearing in inoculated pots. Explanation of symbols: ○ =Strain 147, from spruce seedlings, Washington, D. C., 1910; ▽ =strain 213, from sugar beet seedlings, Washington, D. C., 1911; ■=strain 230, from *Elaeagnus* sp., Kansas, 1913; □ =strain 233, from the same lesion as strain 230. Strains reisolated from these, the results of which appear in experiments Nos. 71 and 72, are indicated by the same signs as the original strains used in the inoculations from which they were taken. The original strains in experiments Nos. 71 and 72 are indicated by arrows.

equal quantities of seed, and the culture substratum used in inoculating was the same for all strains. Experiments 36, 45, 47, 49, and 51 were conducted on plats in out-of-door drill-sown beds, experiment 36 on an alkaline soil, all of which had been heated in a moist condition at a temperature of not less than 80° C. for not less than 10 minutes,[2] and experiments 45, 47, 49, and 51 on a sand which had

[2] This temperature is probably high enough to eliminate damping-off organisms. Tests by Dr. Theodore C. Merrill indicate that the three most virulent parasites so far worked with are killed by placing agar tube cultures for 10-minute periods in water at the following temperatures: *Pythium debaryanum,* 65° C.; *Corticium vagum,* 50° C. for mycelium and 60° C. for sclerotia; *Fusarium moniliforme,* 70° C. Both the Pythium and Fusarium cultures contained spores. The possibility of the survival of oospores which would not be capable of germination for several months was apparently eliminated by the writer, who retained Dr. Merrill's heated Pythium tubes and made final transfers from them 7½ months after heating, still without securing growth. Plenty of typical oospores were present in the part of the heated culture from which transfers were made.

been treated with sulphuric acid followed later by lime. The other experiments included in the graphs were on autoclaved sandy loams in pots in the greenhouse. In these graphs are included all of the results in which the same groups of strains were used repeatedly in different experiments. In figure 1, the values plotted for experiments 36, 49, and 51 are for the number of seedlings which appeared above ground, the heavy inoculations and favorable conditions for damping-off in these experiments being such that even weak strains caused heavy losses and the survivals therefore do not give differential results. Comparison of the survival data in the other experiments in figure 1 with the emergence data for the same strains in that figure and in figure 10 indicates that the strains best able to reduce survival are also the ones best able to reduce emergence.

While the data presented in the graphs are not entirely consistent, it is very evident from them that strains 147, 213, and in a lesser degree 206 were regularly more virulent than most of the strains in tests conducted several years apart on different species of Pinus. It is also evident that certain strains of 186 and 189 which appear in figure 2 are quite regularly of low or doubtful virulence. Strains 50, 183, 192, 211, 212, 230, and 233, whose virulence is apparently intermediate, show a greater variability. In experiments 36, 45, 47, 49, and 51, in which conditions especially favor parasitism, they may cause practically as serious loss as the regularly virulent strains, the best differential results being shown in experiments in which the disease is less favored. The apparent variation in the relative virulence of such strains in different experiments may, of course, mean that their virulence is differently affected by different conditions. It seems rather more probable that the variation in relative activity is to be classed as accidental variation, necessarily great with small units which are subject to numerous uncontrollable variables. It seems entirely possible, however, that part of the observed differences in relative activity may be due to differences, not in virulence, but in the ability of the different strains to maintain themselves saprophytically in different soils during the period between inoculation and the commencement of germination. For example, strains 230 and 233 came from a nursery in southwestern Kansas in which the soil-acidity exponent, as determined by Dr. L. J. Gillespie, of the United States Bureau of Plant Industry, is 8.4. It seems entirely possible that these strains, rather strongly parasitic in some of the experiments, including an experiment on the soil from which they were taken, might prove less able than strains from some other habitats to maintain themselves on some of the eastern soils used in the greenhouse tests. The source of strains 230 and 233 was furthermore a locality where high soil temperatures are to be expected. The fact

that experiments 71 and 72, in which they showed the least virulence, were conducted in a colder greenhouse than any of the other tests may have had something to do with the lower activity indicated for these strains. Variation in the temperature requirements of different strains in accordance with the temperature of the source locality has already been demonstrated by Edgerton (35) for one of the anthracnoses. It is hoped later to determine the temperature and acidity preferences of these two strains as compared with the others used. It should be noted that the consistently weak strain No. 189 (fig. 2), was abnormal in habit, lighter brown, and produced fewer sclerotia than typical strains. The other strains appearing in the graphs showed no conspicuous morphological or cultural differences that were identical. The only other strain which was noticeably abnormal in culture was one from pine seedlings in Kansas, intermediate in habit and color between No. 189 and the typical strains and indicating little more virulence than No. 189 in the few experiments in which it was used. It does not appear in figures 1 and 2, but was included in the experiments reported in the following paragraph. Peltier (99) believes low sclerotium-forming capacity to be a sign of degeneration and low virulence; the writer's experience agrees with his as to virulence, but these two strains showed no other evidence of lack of vigor.

As a further check on the reality of the apparent differences in virulence between different strains, all of the original strains available at the time, a total of 29, were used in the practically duplicate experiments 71 and 72 and the relative survivals of the same strains in the two series mathematically and graphically compared (fig. 11). The very decided correlation between the two experiments indicated by the graph has a coefficient[3] of 0.813 ± 0.042, nineteen times its

[3] The correlation coefficient, a very useful thing for many kinds of biological work, which unfortunately has received little attention from plant pathologists, is explained by Secrist (124, p. 43 et seq.) and the process of computation described (124, p. 453–467). A shorter method of computation is given by E. Davenport (30, p. 465–467); the example he gives is of a series with a large number of varieties, in which the correlation table is employed. Davenport's method is, however, just as useful in such a case as this, in which the number of varieties is too small to make the formal table advantageous. In such a case the computation should be arranged as by Secrist (124, p. 460–461), but the guessed rather than the true mean used and Davenport's formula employed. If the coefficient is $+1$, the correlation is perfect; if it is 0 there is no correlation, and if -1, perfect negative correlation. The significance of a coefficient less than 1 is judged from its relation to its probable error. King (84), in an excellent discussion of correlation, gives rules for judging the degree of significance of the coefficient. The correlation coefficient has its greatest potential usefulness in examining apparent causal relations. It is so used in connection with the relation between the hydrogen-ion exponent and damping-off in considering figure 12 of the present bulletin. Interexperimental, or, as Harris calls them, "interannual" correlation coefficients of the sort used for these Corticium strains have been used by Norton (96, p. 51) in measuring the constancy of rust resistance of asparagus strains, by Harris (54) in demonstrating the constancy of differences in various characters between strains or individuals, and they appear to be useful for this purpose in the present case.

probable error. Peltier's results permit similar correlations for the 18 strains common to his experiments 1 and 1A on carnation cuttings and for the 22 strains common to experiment 1 on cuttings and experiment 2 on seedlings. The coefficients found are decidedly lower than those obtained from the experiments on pine, 0.51±0.117 for the experiments on cuttings and 0.36±0.124 for the comparison of the results on cuttings with the results on seedlings, but nevertheless indicate some interexperimental correlation for the same strains and therefore inherent differences in parasitic ability between the different strains.

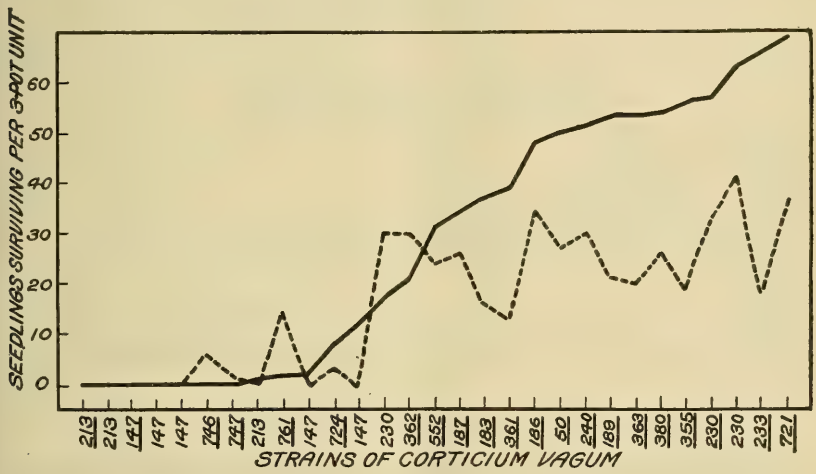


FIG. 11.—Diagram showing the comparative virulence of 29 strains of *Corticium vagum* in two successive inoculation experiments on *Pinus resinosa*. The results in experiment No. 71 are shown by the solid line, the strains being arranged from left to right in the order of descending virulence indicated by the number of seedlings surviving in this experiment. The results from the use of the same strains in experiment No. 72 are shown by the broken line. The obvious correlation between the two curves (coefficient 0.81±0.04) indicates a real difference in virulence between the different strains. The strains indicated by the underscored numbers are original strains and those not underscored reisolations from the original strains in earlier inoculation experiments on pine seedlings.

In the work on pine seedlings, with the possible exception of strains 230 and 233, there was no evidence of attenuation in artificial culture. Strains 147 and 213, isolated in 1910 and 1911, respectively, seemed as strongly parasitic in experiments 71 and 72 (1917 and 1918) as any of the five strains isolated in 1916 or the six strains isolated in 1915.

Of the 20 strains above mentioned, three pairs were isolated under such conditions and showed such later agreement in performance as to indicate their individual identity. For the purposes of consideration in the following paragraph, the one of these probably duplicate strains which happens to have the higher number was eliminated from each pair. The survival figures in pots inoculated with the 17 strains

remaining, giving the mean of the results in experiments 71 and 72, are shown graphically in figure 13, together with the results of some of Peltier's experiments in which other strains were used. Percentages of seedlings damped-off after germination are not included in these and most of the other data on pines because the most virulent strains often entirely prevent germination, and no value for subsequent loss is obtainable. The grouping of most of the writer's strains at the least virulent end of the register (that is, the one with the highest number of living seedlings) is of some interest. The distributions based on the two experiments considered separately

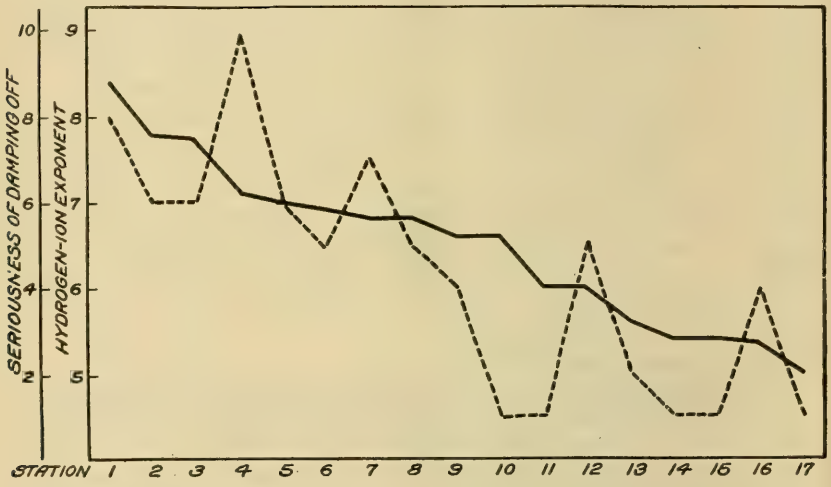


FIG. 12.—Diagram showing the relation between damping-off of conifers (broken line) and soil acidity (solid line). The acidity of soil samples from the different nurseries, determined by Dr. L. J. Gillespie, is reported as P_H7, indicating approximate neutrality while P_H6 indicates ten, and P_H5 one hundred times as great a hydrogen-ion concentration as P_H7; therefore the lower the hydrogen-ion exponent line, the greater the acidity. The seriousness of damping-off at each nursery is on an arbitrary scale in which nurseries with negligible loss are rated as 1, and the nursery which suffered most is rated as 10. These values are estimates, though for some of the nurseries extensive counts were available on which the estimates were based.

agreed very well in this grouping. The minor group at the end of extreme virulence is not taken to indicate an actual grouping but, rather, an artificial one, due to the fact that both the strongest strains and some less strong were thrown into the same group by the lack of additional seedlings for the stronger strains to kill. This lack of additional seedlings constituted a limiting factor. In other words, conditions favored damping-off even in these two experiments too much to permit completely differential results for the more virulent strains. Despite this artificial limit preventing the full variability becoming evident, the coefficient of variability of the survivals

had the high value of 63±9.7 per cent. The graph indicates also a decided, though less extreme, degree of variability for Peltier's strains on carnations; the survivals for the 18 strains which he used in both of his experiments on cuttings have a variability coefficient of 29±3.5 per cent and the 23 strains in experiment 2 on seedlings 55±6.9 per cent.

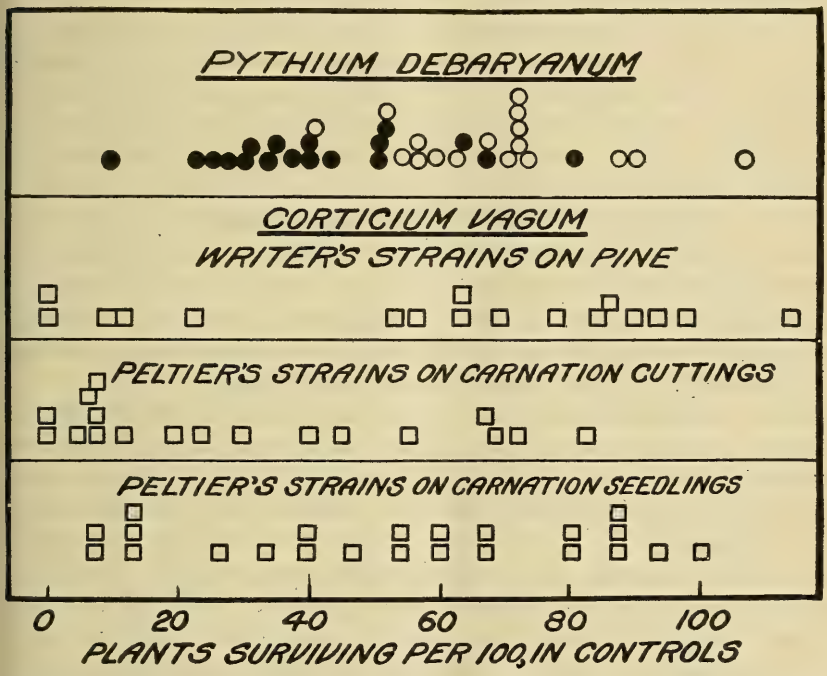


FIG. 13.—Diagram showing the results of inoculations with 17 strains of *Corticium vagum* and 35 strains of *Pythium debaryanum*, arranged in decreasing order of virulence from left to right, as indicated by the survivals in pots of pine seedlings artificially inoculated with them. The Pythium results represent the mean survivals in 5 pots inoculated with each strain in each of experiments Nos. 66, 67, and 68. Each point located is therefore based on the results in 15 pots, 10 of *Pinus banksiana* and 5 of *P. resinosa*. The Corticium results on pine represent 5 or 6 pots each, in two experiments (Nos. 71 and 72) on *P. resinosa*. The outline circles represent *P. debaryanum* strains from East Tawas, Mich.; the solid circles represent strains from other localities. The second row of squares shows the sum of the results in Peltier's experiments Nos. 1 and 1a (99, his table 3). The lowest row of squares shows his results in experiment No. 2 (his table 4).

The strains represented in figure 13, as used on pine, include 1 from bean, 2 from potato, 1 from sugar beet, 1 from Elaeagnus, 2 from *Picea engelmanni*, and 10 from *Pinus resinosa*, *P. ponderosa*, and *P. banksiana*. Two were from Washington, D. C., 2 from New York, 1 from Ohio, 4 from Michigan, 4 from Minnesota, 1 from Nebraska, 2 from Kansas, and 1 from California. The sources of these strains are widely distributed both as to host and locality; they are

rather more representative of the country as a whole geographically than the strains in the larger of Peltier's experiments, though less representative as to host sources. The number is too small to justify conclusions as to the proportion of *Corticium vagum* strains which can be expected to prove strongly virulent on pine. The data are offered merely as a beginning, to which it is hoped experimenters with other strains of *C. vagum* will make additions.

In addition to the strains used in these two experiments, several others which had been lost or for other reasons could not be included in both the final experiments had been previously tested on pines in earlier experiments. Of these, 6 strains, 1 each from alfalfa, sugar beet, *Pseudotsuga taxifolia*, *Pinus banksiana*, *P. resinosa*, and *P. strobus*, gave indications of low virulence on the pines; 3 strains, 1 each from sugar beet, *Pinus sylvestris*, and *P. ponderosa*, gave indications of rather high virulence; while another strain from *P. ponderosa* indicated an intermediate ability to attack pine. Combining these strains with those represented in figure 13, there are data on 27 original strains, of which 8 are roughly classed as strongly virulent on pine seedlings, 14 as weak, and 5 as intermediate.

Edson and Shapovalov (40) have conducted inoculation experiments on potato stems with 6 of the Corticium strains which had been used on pine, including the 5 strains mentioned by them on page 218 and their strains R. XV (the writer's strain 192 of fig. 2) on page 215. Strains 147 and 724, which had proved the most destructive in the inoculations on pine, appeared also rather strongly virulent on potato. Strain No. 186, originally from potato, which had given no definite evidence of parasitism on pine, also proved unable to cause lesions on the potato stems. The remaining 3 strains, all of intermediate virulence on pine, gave results on potato which were less indicative of agreement with the order of virulence on pine. The data suggest that strains strongly parasitic on potato are likely to be strongly parasitic on pine, and vice versa, but the agreement between their results and the writer's is not sufficiently complete to establish the point.

FUSARIUM SPP.

Fusarium is often found on or in damped-off seedlings (24, 46, 60, 94, 120, 137, 141, 142). The early inoculation experiments, conducted in the main with strains not sufficiently described to allow their identification, have been recently summarized (68, p. 537), together with descriptions of inoculation experiments on pine seedlings with four commonly recognized species of Fusarium. These, though not followed by reisolation, gave rather definite evidence that *Fusarium moniliforme* Sheldon was decidedly parasitic and *F. solani* less strongly so. *Fusarium ventricosum* Appel and Wollenw. was indi-

cated as more strongly parasitic than *F. solani*, but in a single test only and with a culture of doubtful purity. *Fusarium acuminatum* E. and E. gave no evidence of parasitism. These results agreed with those of Spaulding (137) in indicating that the ability to attack seedling conifers is not limited to a single species of Fusarium and that *F. moniliforme* is one of the more virulent. The statement by Hartig (61, p. 147–150) that a Fusariumlike fungus was able to corrode the young epidermis of pine seedlings has already been mentioned.

PYTHIUM DEBARYANUM.

Pythium debaryanum Hesse (*Artotrogus debaryanum* Atkinson, *Lucidium pythioides* Lohde) has been known since 1874 (74, 86) as a common cause of damping-off of various angiosperms. The first known observation was made by De Bary about 1864 (74). Despite the large number of hosts on which it has been listed, its parasitism has been definitely established on few. Peters (100) has successfully inoculated sugar beets with pure cultures; at least part of his strains, including presumably part or all of those he used in inoculation tests, were obtained from single spores. Edson (38) working with the same host, reisolated the fungus from inoculated seedlings, and made reinoculations with it. Both find it able to cause root sickness of plants not attacked early enough to be killed outright. Johnson (82) and Knechtel (85) have caused damping-off of tobacco seedlings with it, and the former reported it also able to persist in the cortex and kill the lower leaves of tobacco plants which survived attack. The fungus has long been reputed parasitic on potato tubers and has now been found by Hawkins (70) to be the chief cause of the rot known as "leak" in California. Peters (99) made successful inoculations with pure cultures on cuttings of Pelargonium. Most of the reports of parasitism, however, have been based on microscopic examination or more or less crude inoculation experiments. Noteworthy among the latter are those reported by Hesse (74) on *Camelina sativa* in the original description of the fungus. These were made before pure-culture technique had come into use with fungi, but were so thoroughly checked by microscopic observations at every step in the process that they must be admitted as very good evidence of the parasitism of the fungus. A number of reported angiospermous hosts are listed by Butler (23), Voglino (143), and Johnson (82, p. 34, footnote, and p. 35). Reinking (107) recently reported *Canica papaya* as attacked. A host which the writer has not found in the literature is rice, found by Dr. Haven Metcalf seriously attacked in the seedling stage in a field in South Carolina. A second apparently new host for the fungus is fenugreek (*Trigonella foenum-graecum*). The writer found oospores typical of *Pythium debaryanum* in the tissues of damped-off seed-

lings received by Prof. William T. Horne, from Sonoma County, Calif., with the statement that the disease was seriously affecting the stand. The fungus was easily isolated, and the results of successful inoculations on pine with the cultures obtained are included in Table V (p. 47). A fungus resembling *P. debaryanum* was also found in damped-off cowpea (*Vigna* sp.) seedlings grown in rotation with pines at a Nebraska nursery.

Pythium equiseti Sadebeck, reported as parastic on the prothallia of *Equisetum arvense*, was successfully used by Sadebeck (117) in crude cross-inoculations direct from *E. arvense* to potato tubers. De Bary (5) reversed the direction of the experiment between cryptogamous and phanerogamous hosts by successfully inoculating prothallia of *Equisetum arvense* with *Pythium debaryanum* directly from diseased Lepidium seedlings. He also secured positive results on prothallia of the fern *Todea africana* by the same method. The Equisetum prothallia he found to be especially favorable media on which to develop *Pythium debaryanum*. Fischer considers the fungus found by Bruchmann (17) and Goebel (49) on prothallia of *Lycopodium* sp. as probably identical with *P. debaryanum*. A careful reading of the original articles is sufficient to show that the symbiotic fungus which they described was an entirely different organism. *Saprolegnia schachtii* and *Sporodospora jungermanniae*, reported on two of the Hepaticæ, are of doubtful position (42, p. 403), though Butler (23, p. 89), after a survey of the literature, apparently favors the view that the former is distinct from the damping-off fungus. De Bary (5) reported Vaucheria and Spirogyra apparently immune against *P. debaryanum*.

Early references to *Pythium debaryanum* in connection with gynosperms seem to have been based on the probability that it would be found to be the cause of damping-off in conifers (6; 97; 134, p. 27). The first actual finding of the fungus in any gymnosperms of which the writer is aware is indicated by a label marked *Pythium debaryanum* in the handwriting of Mrs. Flora W. Patterson on a package of coniferous seedlings from a New York nursery collected in 1904.[4] The seedlings, judging from the several rather long cotyledons and the fact that both cotyledons and primary leaves are denticulate, are probably of one of the species of Pinus having medium-sized seed. In 1908 Dr. R. J. Pool, of the University of Nebraska, and his student, Mr. H. S. Stevenson, obtained in culture from damped-off coniferous seedlings a nonseptate fungus which was probably *Pythium debaryanum*, but which formed no distinctive spores on the media on which it was grown. A year later the writer obtained the fungus from pine seedlings at the same nursery and reported it as

[4] In the Office of Pathological Collections, United States Bureau of Plant Industry.

parasitic on pines in preliminary inoculation experiments (62). In 1910 Spaulding (137) found it on spruce in New York, and Hofmann (76) later made successful inoculations on both pine and spruce seedlings, using *P. debaryanum* cultures both from aerial trap plates and from recently damped-off seedlings of cabbage, radish, and Russian thistle (*Salsola tragus*). Hofmann's work, detailed notes of which the writer has been permitted to examine, was done with cultures which were contaminated by molds, but was checked up by microscopic examination of the lesions resulting, which showed the affected tissues filled with nonseptate hyphæ. His results are taken as a rather strong indication that *P. debaryanum* attacks spruce as well as pine and that the fungus attacking conifers is physiologically as well as morphologically identical with that causing the damping-off of angiosperms.

There thus appears from the literature to be reason to believe that *Pythium debaryanum* is parasitic on representatives of two groups of the Pteridophyta and on gymnosperms, as well as on various monocotyledons and dicotyledons, a range of hosts not only remarkable but perhaps unequaled in our present knowledge of plant parasites. Final published proof of parasitism seems to be available for three or four species of dicotyledons only. Additional inoculations on conifers with strains isolated from various other hosts are reported in the present bulletin. Some of the detailed evidence necessary for complete proof of the parasitism of the Pythium on conifers, lacking in experiments previously reported because of the doubtful purity of the cultures used and failure to reisolate and reinoculate with the organism, is also given here, together with evidence of the ability of the parasite to cause root sickness of pines too old to suffer from damping-off.

Descriptive data of interest on *Pythium debaryanum* have been supplied by Hesse (74), De Bary (5), Ward (144), Miyake (89), Butler (23), and Butler and Kulkarni (24). An important contribution to the physiology of the fungus and the factors controlling its passage through the tissues of one of its hosts has recently been made in the previously mentioned paper of Hawkins and Harvey (71).

IDENTITY AND ISOLATION.

The fungus in the writer's cultures referred to *Pythium debaryanum* Hesse has been so called for the following reasons:

(1) The morphological characters agree with those described and figured for *Pythium debaryanum* by other workers and with those of strains obtained from Dr. H. A. Edson under this name.

(2) The absence of zoospores in the writer's cultures agrees with the experience of others with *Pythium debaryanum* (2, 5, 23, 24, 38, 100), all workers with pure cultures having obtained zoospores infrequently, if at all. The earliest work by Hesse (74) in which zoospores were apparently produced

readily at certain times of the year was done before the development of pure-culture methods. Water cultures kept in the dark and in the light, at constant and at varying temperatures, with nutrient substrata consisting of steamed or autoclaved fragments of potato, carrot, sweet potato, turnip, sugar beet, corn meal or rice, nutrient agar, sugar-beet seedlings, and insects have all produced only sexual fruiting bodies and chlamydospores (the so-called conidia).

(3) The successful cross-inoculations, those which Edson (38) used on sugar-beet strains and the writer had found parasitic on pine and had used on pine, strains which Hawkins had found parasitic on potato tubers and Edson on sugar beets, confirm the work of Hofmann (77) in indicating that the Pythium which causes the damping-off pine is a parasite on entirely unrelated species of host plants, a commonly recognized characteristic of *Pythium debaryanum*.

The organism is easily isolated from recently damped-off coniferous seedlings or from soil direct by placing the seedlings or a lump of soil at the edge of a Petri dish of solidified prune agar and transferring to tubes mycelium from the advancing edge of the resulting growth. It has been found in or obtained from damped-off conifers in California, Kansas, Nebraska, Minnesota, and the District of Columbia, as well as in cultures made by Mr. Glenn G. Hahn in Michigan. *Picea engelmanni*, *P. sitchensis*, *Tsuga mertensiana*, *Pinus nigra austriaca*, and *Pseudotsuga taxifolia* are the coniferous hosts from which cultures of *Pythium debaryanum* have been obtained. It has been isolated directly from soil not only in coniferous seed beds but from open grassland in California not adjacent to any seed bed or cultivated crop. Unless Mucor is abundant, Pythium is commonly obtained in apparently pure condition on the first transfer from the plate, as prune agar appears unfavorable for most bacterial growth while allowing rapid spread of the Pythium. On media made from prunes which taste sweet and with a total gross weight of not more than 40 or 50 grams per liter of medium, the Pythium will make a rapid growth, often extending radially 1 mm. per hour at temperatures in the neighborhood of 22° C. and produce both chlamydospores and oospores. A less valuable medium for isolation work, but more convenient for subcultures than any other which has been tested, is autoclaved corn-meal agar. The growth is not luxuriant, but spores are always formed and the cultures seem to be as long lived as those on any other medium, retransfer being rarely necessary more often than twice a year. Much stronger growth and more abundant fruiting is obtained on such media as sugar-beet or rice-stem agar, but the leathery surface of the culture on such media makes transferring difficult. On rice grains, corn-meal mush, beef agar, and on corn-meal agar plus 2 per cent dextose or sucrose no spores are formed and the cultures are short lived, though growth is heavy and on the last-named medium extremely rapid. On agar containing the juice from sour prunes or on corn-meal agar prepared without subjecting it to the high temperature of the autoclave, both growth and fruiting have been very poor or even lacking.

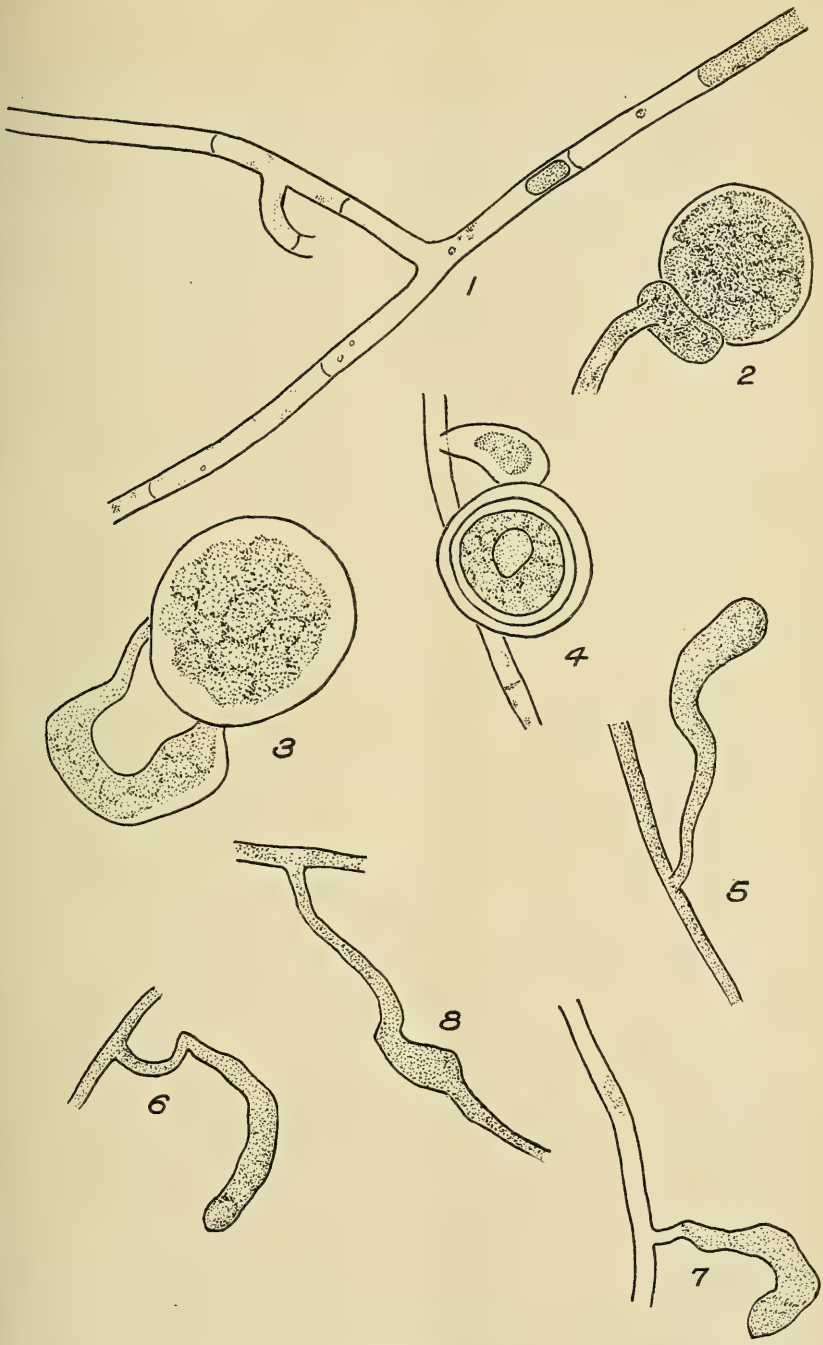
In both artificial cultures and in the tissues of coniferous and dicotyledonous hosts the numerous strains observed showed no conspicuous differences in the size or other characters of the spores produced, though noticeable and constant abnormality was found in one strain in the readiness with which spores were produced and in two strains in the ratio between chlamydospores and oospores in agar cultures. In the first-mentioned strain, obtained from pine in Kansas, and in cultures reisolated from seedlings inoculated with it, both chlamydospores and oospores are produced tardily and so scantily that it is often difficult to find them. In most strains, on the other hand, almost the entire contents of the mycelium are promptly emptied into the spores as soon as the limits of rapid vegetative growth are reached. In another abnormal strain from pine from the same locality, and in still another furnished by Hawkins from a California potato, chlamydospores are produced in large numbers, but oospores are few. In many other strains, including several from California, the opposite condition obtains, oospores in plate cultures being decidedly more numerous than chlamydospores. These peculiarities of particular strains seem to be fairly constant characters, the first abnormal strain mentioned having been under observation for more than three years without any change in its tendency to scanty fruiting, and the low ratio of oospores to chlamydospores having been constant during the shorter periods over which the observation of the other strains extended. In view of the small variation between different strains in the matter of speed of growth, a purely vegetative character, this variation in reproductive habit is somewhat surprising. The strain which produced spores infrequently was unquestionably parasitic, though it killed fewer seedlings than the average *Pythium debaryanum* strains. The strains with the high ratio of chlamydospores were both of at least average virulence on pine.

Oospores in the strains the writer has had in culture, whether examined in agar, in water cultures, or in root tissues, have ordinarily been somewhat larger than the diameter of 14 or 15 to 18 μ given in a number of the descriptions. The maximum range has been 12.8 to 20.6 μ, the same strain sometimes being well down within the usual size range and sometimes ranging from 17 to 20 μ. The largest oogones observed were 26 μ in diameter. Various stages of fertilization are shown in Plate I, figures 2 to 4. Chlamydospores attain a maximum diameter in the case of the limoniform intercalary forms of 32 μ, and spherical chlamydospores sometimes reach a diameter of 28 μ. There is no lower limit for these bodies, as under unfavorable conditions—e. g., in sour-prune agar—they are sometimes all less than 15 μ in diameter, and the smaller ones are little larger than the

hyphæ which bear them. Both oogones and chlamydospores may be either terminal or intercalary.

The normal hyphæ are large, varying from 3 to 7 μ and sometimes more in diameter. Typical hyphæ, showing the false septa developed at the boundary of the protoplasm and the portions of the hyphæ which have been evacuated in the extension of the younger parts, are shown in Plate I, figure 1. At points at which the ends of hyphæ come in contact with the glass of the culture dish, peculiar contact swellings are produced (Pl. I, figs. 5 to 7), much the shape and size of antheridia, but not walled off from the adjacent hyphæ and having no apparent significance in the life history of the fungus. These are not always terminal (Pl. I, fig. 8). It is noteworthy that Hesse described contact swellings at the tips of the hyphæ just before penetrating the epidermis of *Camelina sativa.*

The asexual nonsporangial fruiting bodies of *Pythium debaryanum* are referred to as chlamydospores rather than as conidia, though in most of the previous literature the latter term has been used for them. Hesse called the terminal bodies conidia and the intercalary, gemmæ (74). It is believed that the best terminology and the one which should be followed for all fungi, as it now is for most, is that which limits the term conidium to a spore which is adapted primarily for aerial distribution or which is at least readily separated as soon as it is mature from the parent hypha from which it arises. The most typical conidium, in fact, is a spore which is abstricted by the parent hypha at maturity. The asexual spores of this Pythium remain attached to the parent hyphæ indefinitely even after the hyphæ are dead and empty. It is a common thing to find numbers of these bodies in water cultures, still attached to hyphæ which are so completely empty that it is only with favorable lighting that their thin colorless walls can be seen. So firm is the attachment that vigorous shaking is required to release any considerable proportion of the spores. It seems probable that in nature the spores are released chiefly as a result of the destruction of the hyphæ walls by bacteria. While there is reason to think that *Pythium debaryanum* is sometimes disseminated by wind, it is by no means certain that it is through the medium of these spores. It is true that these bodies have thinner walls than are commonly found in chlamydospores of some other fungi, but they have somewhat thickened walls as compared with the vegetative hyphæ, and they are commonly intercalary. These facts, and the indications that they are better able to withstand unfavorable conditions than are the hyphæ, all tend to entitle them to rank as chlamydospores. De Bary (5) speaks of them as "dauerconidia." Their ability to stand drying is not entirely demonstrated, but is indicated by the relative longevity of the fungus on different media. On beef agar and on rice, on which no spores are



PYTHIUM DEBARYANUM FROM ARTIFICIAL CULTURES.

FIG. 1.—Hyphæ, showing old portions of hyphæ and false septa separating them from the portions still containing protoplasm. FIGS. 2 to 4.—Various stages of oospore formation. FIGS. 5 to 8.—Hyphal swellings at points of contact with glass. From camera-lucida drawings.

formed, a few tests indicate that the fungus is very short lived, sometimes dying in a month. On media on which spores are produced, transfers any time before the sixth month, and often as late as the tenth month, start immediate growth on fresh media. This is true even for strains which produce few or no oospores. The immediate commencement of growth from cultures 3 or 4 months old is taken as an indication that the new growth results from the asexual spores, as oospores are commonly believed to require a resting period of five or more months before they are able to germinate (5, 38).

INOCULATION ON STERILIZED SOIL.

Pythium debaryanum has been used in inoculation in pots of recently autoclaved soil in 16 different series of tests. In 10 of these, fragments of agar cultures were scattered over about one-fourth of the area at the side of each pot when seed was sown; in 2 of these 10 and also in 2 other tests some pots were inoculated over their entire surface. In every one of these 12 heavily inoculated series positive results were indicated by smaller emergence and where any considerable number of sprouting seeds escaped the fungus by heavier damping-off loss in the inoculated pots than in the controls. In some cases the fungus killed all or practically all of the seed or seedlings in the inoculated pots before they emerged from the soil.

In a total of 7 series, part or all of the pots received lighter inoculations, consisting of one or two small fragments of an agar culture placed just below the surface of the soil at the edge of each pot. In 5 of these success was indicated. In the sixth and seventh also of these lightly inoculated sets, there was more damping-off in the inoculated pots than in the controls, but the difference was negligible. The damping-off caused by light inoculations was in general distinctly less than that resulting from broadcast inoculations. To sum up the evidence: Sixteen separate experiments were conducted with *Pythium debaryanum* on pine seedlings in autoclaved soil, and in every one fewer seedlings survived in the inoculated pots than in the checks; the difference in most of the experiments was large.

Of the successful inoculation experiments—that is, those in which the difference between the inoculated pots and the checks seemed significant—9 series included jack pine (*Pinus banksiana*), 7 series western yellow pine (*P. ponderosa*, Colorado and New Mexico seed), and 3 series red pine (*P. resinosa*). In addition to the pines, Douglas fir (*Pseudotsuga taxifolia*, Colorado seed) was grown in two large plats in one of the earlier series, one being inoculated over its entire surface with *Pythium debaryanum*. Because of the poor quality of the seed in the test on Douglas fir, too few seedlings were obtained to furnish a decisive test, but the difference in the emergence in the inoculated plat and the control affords preliminary evidence that

Pythium can cause the "germination-loss" type of damping-off in Douglas fir as well as in species of Pinus. Of the seeds sown in the control plat 43 produced seedlings which appeared above the soil, while only two seedlings appeared from an equal number of seeds sown in the inoculated plat.

Altogether, 38 strains, excluding reisolations, have been tested on one or more of the 3 pine species. Strains from both the Pacific coast and the eastern United States and from a number of hosts other than pines were among those used. With the exception of two or three strains from a pine nursery in Michigan, the use of which was followed by so little damping-off as to leave their parasitism uncertain, all of the strains proved parasitic under favorable conditions, though some were more virulent than others. The positive results in the 14 successful experiments are based on the comparison of a total of approximately 1,160 inoculated pots with 195 control pots.

TABLE III.—*Inoculation experiments with Pythium debaryanum in pots of sterilized soil.*

Series, experiment number, and host.	Pythium strain.		Number of pots.	Inoculation method.	Results.		
	No.	Initial strain from which it was reisolated.			Emerged (per 5-pot unit).	Damping-off after germination (per cent).	Survival (per 5-pot unit).
SERIES A.—Initial inoculations:							
No. 58, Pinus banksiana..	218		5	Agar cultures broadcast at one side of pot.	1	100	0
	Controls.		5	No inoculum	74	0	74
	..do		5	.....do	82	0	82
No. 58, Pinus ponderosa..	295		5	Agar cultures at single point in each pot.	41	28	30
	Controls.		5	No inoculum	55	0	55
No. 62, Pinus banksiana..	258		5	Agar cultures broadcast at one side of pot.	16	81	3
	..do		5	.....do	18	89	2
	Controls.		5	No inoculum.	90	0	90
	..do		5	.....do	82	0	82
	..do		6	.....do	82	0	82
	338[a]		5	Agar cultures broadcast at one side of pot.	14	72	4
	347[a]		5	.....do	3	67	1
	348[a]		5	.....do	13	67	4
	Control[a]		5	No inoculum	78	0	78
SERIES B.—Reisolated strains:							
No. 62, Pinus banksiana..	338	No. 295 (in P. ponderosa, expt. 58).	5	(b)	14	72	4
	Controls.		5		78	0	78

[a] A different soil used in these pots from that used with strain 258 and the first three control units.
[b] All inoculations with fragments of agar cultures scattered broadcast at one side of the pot, including about one-fourth of its area. Nothing was added to the controls in experiment 62, but sterile agar was added to the controls in experiments 66, 67, and 68.

TABLE III.—*Inoculation experiments with Pythium debaryanum in pots of sterilized soil*—Continued.

Series, experiment number, and host.	Pythium strain.		Number of pots.	Inoculation method.	Results.		
	No.	Initial strain from which it was reisolated.			Emerged (per 5-pot unit).	Damping-off after germination (per cent).	Survival (per 5-pot unit).
Series B.—Reisolated strains—Continued.							
No. 66, Pinus banksiana..	338.....	No. 295 (in P. ponderosa, expt. 58).	5	(a)	9	67	3
	345.....	No. 218 (in P. banksiana, expt. 58).	5	(a)	15	33	10
	414.....	No. 258 (in P. banksiana, expt. 62, 2d unit).	5	(a)	36	25	27
	415.....	.....do.....	5	(a)	59	10	54
	419.....	No. 348 (in P. banksiana, expt. 62).	5	(a)	25	100	0
	450.....	No. 347 (in P. banksiana, expt. 62).	5	(a)	41	72	11
	Controls.	.....	25	.....	75	14	64
No. 67, Pinus banksiana..	338.....	No. 295 (in P. ponderosa, expt. 58).	5	(a)	7	57	3
	345.....	No. 218 (in P. banksiana, expt. 58).	5	(a)	24	37	15
	414	No. 258 (in P. banksiana, expt. 62, 2d unit).	5	(a)	57	24	44
	415.....	No. 258 (in P. banksiana, expt. 62, 1st unit).	5	(a)	30	37	19
	419.....	No. 348 (in P. banksiana, expt. 62).	5	(a)	62	65	22
	450.....	No. 347 (in P. banksiana, expt. 62).	5	(a)	53	27	39
	Controls	.....	23	.....	87	5	83
No. 68, Pinus resinosa....	338.....	No. 295 (in P. ponderosa, expt. 58).	5	(a)	85	26	63
	345.....	No. 218 (in P. banksiana, expt. 58).	5	(a)	76	24	58
	414.....	No. 258 (in P. banksiana, expt. 62, 2d unit).	5	(a)	98	14	84
	415.....	No. 258 (in P. banksiana, expt. 62, 1st unit).	5	(a)	92	11	82
	419.....	No. 348 (in P. banksiana, expt. 62).	5	(a)	95	45	52
	450.....	No. 347 (in P. banksiana, expt. 62).	5	(a)	84	40	51
	Controls	.....	18	.....	104	0	104

[a] All inoculations with fragments of agar cultures scattered broadcast at one side of the pot, including about one-fourth of its area. Nothing was added to the controls in experiment 62, but sterile agar was added to the controls in experiments 66, 67, and 68.

As has been stated, securing positive results did not always mean that the control pots remain uninfected. Even with the most careful treatment and the use of boiled water throughout the experiment

it proved difficult to keep the control pots entirely free from damping-off. Cultures from seedlings which damped-off spontaneously in control pots indicated that Pythium as well as Fusarium may be introduced by accident, even when insects, birds, and rodents are excluded. This agrees with the evidence of Hofmann (77) that *Pythium debaryanum* is sometimes disseminated by wind, despite its apparent lack of adaptation to wind distribution. It is also indicated, however, that unheated tap water increases damping-off when used on control pots and probably carries this semiaquatic fungus. Notwithstanding infections in the controls of a number of the experiments, it is believed that the large number of pots whose results have been considered in drawing conclusions, the fact that the Pythium pots lost more heavily than the controls in every one of the 16 experiments, and the magnitude of the differences between both the emergence and subsequent damping-off figures for the inoculated pots and the controls in most of the experiments establish the parasitism of the fungus in inoculation on autoclaved soil without it being necessary to present all the evidence in detail. The pot series which involved reisolation and reinoculation (Table III), together with the results given for other purposes in Tables V and VI, seem sufficient by themselves to establish a parasitic relationship.

REISOLATION AND REINOCULATION.

In a number of the experiments dead seedlings in the inoculated pots were examined and typical Pythium hyphæ and spores were found. In three of the experiments in which the controls remained entirely free from disease up to the time the experiment was closed, reisolations and reinoculations were made in accordance with the usual rules of proof. The results are given in Table III.

From Table III it will be seen that five strains reisolated from *Pinus banksiana* and one strain reisolated from *P. ponderosa* gave positive results in pots of *P. banksiana* and *P. resinosa*. In addition to the reinoculations shown in the table, the strain reisolated from *Pinus ponderosa* (No. 338) was again reisolated in duplicate from *P. banksiana* in experiment 62, and both these secondary reisolations gave cultures which were parasitic on *P. banksiana* and *P. resinosa* in subsequent inoculations.

That the organisms reisolated were actually the same as those used in the initial inoculation is indicated not only by the absence of disease in the control pots of experiments 58 and 62, but by the distinctive characters of some of the strains. In general, cultures reisolated from strongly parasitic initial strains were themselves strongly parasitic and vice versa. This is shown by comparing the figures for the initial and reisolated strains, as shown in Table IV. Each figure represents the average results in 10 pots of jack pine and 5 of red

pine in experiments 66, 67, and 68 combined. The figures are relative, the mean survival of 47 different strains used in all three experiments being taken as 10. A survival figure above 10 therefore means that the strain was less destructive than the average Pythium, and a figure below 10 indicates more than average virulence. As strain 218 was not used in these three experiments, strain 345 can not be compared.

TABLE IV.—*Comparative virulence of original cultures and reisolated strains of Pythium debaryanum in experiments 66, 67, and 68.*

Pythium strain.	Description.	Relative survival.	Pythium strain.	Description.	Relative survival.
No. 258	Original culture	16	No 409	Reisolated from 338	9
No. 414	Reisolated from 258	12	No. 347	Original culture	4
No. 415	do.	12	No. 450	Reisolated from 347	7
No. 295	Original culture	4	No. 348	Original culture	10
No. 338	Reisolated from 295	4	No. 419	Reisolated from 348	4
No. 408	Reisolated from 338	6			

These figures are not absolutely consistent, but are to be viewed as contributing to the evidence furnished by the absence of damping-off in the control of experiments 58 and 62 that the cultures reisolated in those experiments were actually identical with the original strains. A further proof of this identity is in the fruiting tendencies of the strains. Both Nos. 414 and 415, the strains reisolated from original strain 258, exhibited the peculiarly sparse spore production which has been characteristic of strain 258 for the entire period during which it has been in culture. The other reisolated strains, taken from pots inoculated with normally fruiting strains, all showed normal spore production.

PURITY OF CULTURES.

A slight deficiency in the evidence as to the parasitism of *Pythium debaryanum* both in the writer's work and apparently in all previous investigations except those of Peters (100) and possibly Knechtel [5] is the lack of single-spore cultures. The large number of strains which have remained apparently pure through numerous subcultures and have retained their individual characteristics as to virulence and fruiting tendencies (one strain having been carried on artificial media continuously for eight years without material change) give very strong justification for believing that the cultures used were pure. In three early inoculation tests the cultures used were afterwards found to have been contaminated by bacteria carried by mites; the positive results obtained in these three were the basis of the ear-

[5] Knechtel's work in Rumanian has been available to the writer only in the German abstract, which makes an ambiguous statement on this point.

liest report of pathogenicity (62), but have not been used as evidence in the present bulletin, though the contaminating bacteria in one of them, when tested independently, showed no evidence of parasitism. In all the experiments mentioned in the foregoing as giving positive results with Pythium the cultures used were apparently pure.

Cultures from single chlamydospores should be reasonably easy to secure, part of the chlamydospores in water cultures being separable from the mycelium by vigorous shaking, and further inoculation tests with cultures so obtained are probably desirable. The experiments so far conducted are believed to be sufficiently conclusive, however, for all practical purposes. For isolation of absolutely pure lines of this or any other cœnocytic fungus, it is evident, as pointed out by Dr. W. H. Weston (146), that isolations should be made from the uninucleate swarm spores. For the determination of the bare fact of pathogenicity such a refinement would be superfluous.

CROSS-INOCULATIONS.

The physiological identity of the Pythium attacking coniferous seedlings with the one which attacks dicotyledons is indicated by the results of several inoculation experiments. The last two experiments, one with jack pine and one with red pine for the host, are the most comprehensive and give results sufficiently decisive so that quotation of the corroborative evidence from earlier experiments is considered unnecessary. The results appear in Table V. Each unit consisted of five 3-inch pots except in the controls, in which 23 pots were used in the jack-pine experiment and 18 in that with red pine. In the second experiment, separate records were kept of the survival in each pot, and the probable error calculated from the controls was less than two seedlings per pot for a single pot, less than 0.9 for a mean of 5 pots, and less than 0.5 for the mean of the 18 control pots. While the number of controls was, of course, insufficient to furnish an exact basis for such a calculation, the small value found tends to confirm the impression gained from inspection of the table that considerable confidence can be placed in the results.

The difference appearing in Table V between jack pine and red pine in point of susceptibility to germination loss from Pythium agrees with field observations in Nebraska, the red pine at the Bessey Nursery, though on the whole more susceptible than jack pine to damping-off losses, having given indication of more resistance to the disease for the first week or two. Inoculations in other experiments on western yellow pine indicate that the strains which attack it are identical with those attacking jack pine and red pine.

The conclusion reached from the cross-inoculation results is that the Pythium causing damping-off of the three species of pine men-

tioned is identical with *Pythium debaryanum*, causing leak of potato tubers and the damping-off of seedlings of two dicotyledonous families.

TABLE V.—*Results of inoculations on jack pine and red pine with Pythium debaryanum from various hosts.*

Strain.	Host from which isolated.	Inoculation results.					
		On jack pine.			On red pine.		
		Emerged (per 5-pot unit).	Damping-off (per cent).	Survival (per 5-pot unit).	Emerged (per 5-pot unit).	Damping-off (per cent).	Survival (per pot).
	Dicotyledons:						
No. 131 [a]	Potato tuber	45	36	30	101	23	15.6
No. 810 [b]	Do	45	34	30	62	41	7.4
	Average potato	45	35	30	82	32	11.6
No. 294 [c]	Sugar-beet seedlings	50	8	46	79	36	10.2
No. 295 [c]	Originally potato strain 131, but twice inoculated on and reisolated from sugar-beet seedlings by Edson	28	32	19	62	48	6.6
No. 296 [d]	Sugar-beet seedlings	19	32	13	68	58	5.8
	Average, sugar beet	32	24	26	70	47	7.4
No. 529	Fenugreek seedlings [d]	36	31	25	102	26	15.0
No. 530	Do	60	49	31	108	22	16.8
	Average, fenugreek	48	40	28	105	24	16.0
	Conifers:						
No. 258	Western yellow-pine seedlings	58	9	53	109	17	18.0
No. 550	Sitka spruce seedlings	15	80	3	39	98	.2
No. 555	Engelmann spruce seedlings	42	29	30	45	70	5.0
	Average, spruces	29	55	17	42	84	2.6
	Controls	87	5	83	104	0	20.9

[a] Furnished by Mrs. C. R. Tillotson: has been used successfully on sugar-beet seedlings by Dr. H. A. Edson.
[b] Furnished by Dr. L. A. Hawkins: cause of leak.
[c] Furnished by Dr. H. A. Edson.
[d] Diseased material furnished by Prof. W. T. Horne.

VARIATIONS IN VIRULENCE OF PYTHIUM STRAINS ON PINE.

In *Pythium debaryanum* strains, as in the case of *Corticium vagum*, there appeared to be a considerable difference in the parasitic activity of different strains used in the same experiment. Figures 14, 15, and 16 show graphically the results from inoculations with different strains of *P. debaryanum* in all the experiments in which it was possible to compare directly the activity of different strains. All the inoculations involved at the time of sowing the addition to the soil of cultures on nutrient media in recently autoclaved 3-inch pots. In experiment 31C the inoculum fragments were scattered over the whole pot, in 31D at only one point in each pot, and in the others were distributed over about one-fourth of the pot's area. As noted elsewhere, the variations observed in the results may have been due in part to differences in the ability of the different strains to main-

tain themselves saprophytically in the soil used rather than entirely due to difference in virulence.

The data shown in figures 15 and 16 indicate in the first place rather more accidental variations in the results with Pythium than with Corticium (see figs. 1, 2, 10, and 11). The agreement between original and reisolated strains from the same original source is decidedly less good than in the case of Corticium (see experiments 71 and 72, figs. 10 and 11). In general, there are only two strains of

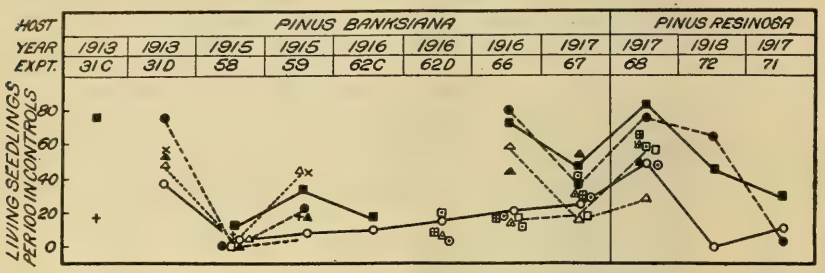


FIG. 14.—Diagram showing variations in virulence as indicated by the living seedlings in pots of autoclaved soil inoculated with different strains of *Pythium debaryanum*. For experiments Nos. 31 and 66 to 72, inclusive, the surviving seedlings at the end of two or three weeks after germination are shown. For the other experiments damping-off was so heavy in the inoculated pots that the survivals did not give differential results for the different strains, and the germinations are therefore shown. The reports are based for experiments Nos. 71 and 72 on 2 or 3 pots for each strain in each experiment, and for the other experiments on not less than 5 pots for each strain. In experiments Nos. 66, 67, and 68 the number of pots in each experiment for the strains whose reisolations were also used varied from 10 to 40 for each strain, the results of the separate 5-pot units being shown in figure 15. The strains indicated by the different symbols are as follows: *From potato:* ●=Strain 131, isolated in 1909, California. Furnished by Mrs. C. R. Tillotson. *From sugar beet:* ○=Strain 295 and its reisolations from pine. No. 295 was furnished by Dr. H. A. Edson as a reisolation of strain 131, after having been passed by him through two generations of sugar-beet seedlings. ▲=Strain 294, isolated in 1912. Furnished by Dr. Edson. △=Strain 296, isolated in 1912, Wisconsin. Furnished by Dr. Edson. ×=Strain 297, originally from pine, Nebraska, 1911. Passed through two generations of sugar-beet seedlings by Dr. Edson. *From pine seedlings:* +=Strain 255, Kansas, 1913. Chlamydospores numerous; oospores rare. ■=Strain 258 and its reisolations, Kansas, 1913. A sparsely fruiting strain. □=Strain 218 and its reisolation, Kansas, 1912. ⊙=Strain 347 and its reisolation, Washington, D. C., 1915. ⊡=Strain 348 and its reisolation, Washington, D. C., 1915. ◬=Strain 349, Washington, D. C., 1915. ⊞=Strain 354, Minnesota, 1915.

Pythium which can be said to have definitely shown difference in activity continuing through several years and on different species of pine. These are strains 295 and 258. As No. 258, the weak strain, has also been found abnormal in its fruiting tendencies, the evidence in these graphs does not indicate a decided difference in virulence between different typical strains of *Pythium debaryanum*. The other strain, which seems rather uniformly weaker than No. 295, is No. 131, which according to Dr. Edson's records was originally the

same strain, No. 131 having been twice used in his inoculation experiments on sugar beets and strain 295 recovered from the second experiment. The apparent difference between this original strain and its supposed reisolation may possibly be due to the treatment given strain 131. Before it was used in any of the experiments shown but after it had been used by Dr. Edson, it was allowed to get very dry and was revived with great difficulty, growth being very slow. While it apparently recovered all of its normal growth qualities after one or two transfers, it is thought that this may possibly explain the apparently decreased virulence in the later experiments.

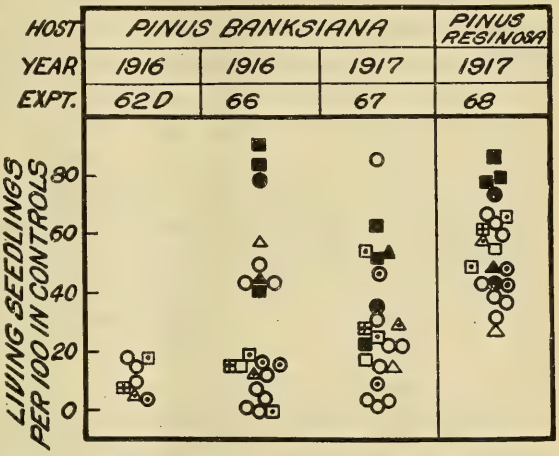


FIG. 15.—Diagram showing the results of inoculations with strains of *Pythium debaryanum*. This figure supplements figure 14, giving the results for original and reisolated strains independently. Each point plotted is based on the results in five pots. The object of this diagram is to give an idea of the degree of variability in the success of inoculations. An explanation of the symbols used will be found in the legend of figure 14.

The failure to secure as definite indications of constant virulence differences as were obtained for several of the Corticium strains is believed to be in part due to a smaller actual difference between the different Pythium strains appearing in the graphs and in part to a larger accidental variation between results in pots inoculated with the same strain. The growth of Pythium on agar media is much more affected by variations in the substratum than is the growth of Corticium, and it is rather natural to expect greater variations when the two fungi are added to autoclaved soil. In experiments 66, 67, and 68 a number of strains not used in the earlier experiments were tested, in addition to the strains previously used. The survival results for all the different strains, both original and reisolated, 47 in all, are shown graphically in figure 16. The results in experiments 66 and 67, both on *Pinus banksiana*, are averaged and taken as the subject, while the results with the same strains in experiment 68 are made relative and shown by the broken line. The correlation between the performance of the same strains on the two species of pine is by no means as clear in the graph as it was in the case of the Corticium strains (fig. 11). The areas bounded by the broken line and

the horizontal line showing the location of the mean for experiment 68 are much larger below the means than above it in the left-hand portion of the graph, while the reverse is true in the right-hand portion. To this extent the relative activity of the strains in this experiment agrees with the performance of the same strains in the two jack-pine experiments, as shown by the solid line. It can not be decided from an inspection of the graph whether there is a real agreement, in view of the large accidental variation present. However, the correlation coefficient, 0.446 ± 0.079, five and one-half times its probable error, indicates a considerable correlation, not as good as was found for the Corticium strains, but sufficient to establish a strong presumption that observed differences in activity of the dif-

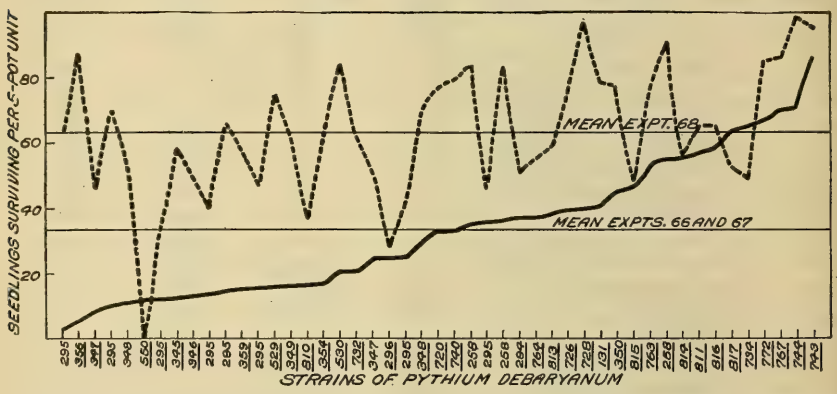


FIG. 16.—Diagram showing the comparative virulence of 47 strains of *Pythium debaryanum* in successive inoculation experiments on species of Pinus. The results in experiments Nos. 66 and 67 (on *Pinus banksiana*) are shown by the solid line, the strains being arranged from left to right in the order of descending virulence indicated by the number of seedlings surviving in those experiments. The results from the use of the same strains in experiment No. 68 (on *Pinus resinosa*) are shown by the broken line. Such correlation as there is between the two curves (coefficient 0.45 ± 0.08) goes to indicate a real difference in virulence between the different strains. The strains indicated by the underscored numbers are original strains, and those not underscored are reisolations from the original strains in earlier inoculation experiments on pine seedlings.

ferent strains in these inoculation experiments were in part actually due to differences in the capacity of the strains.

It has been suggested in the foregoing that the difficulty in demonstrating constancy in the difference in virulence between the various strains of *Pythium debaryanum* is due in part to the lack of such extreme differences as were observed between the various Corticium strains. Figure 13 shows the distribution of the different original Pythium strains according to the virulence indicated in the three inoculation experiments of figure 16 (application to autoclaved soil at the time of sowing). Each value plotted is based on the average results in 15 pots. Of the strains used, 21 were from species of pine, 1 from spruce, 2 from potato tubers, 2 from fenugreek, 3 from sugar beet, and 6 from soil direct. Despite the considerable number of

strains, they are not much more representative than the smaller number of Corticium strains experimented with. All of the strains from soil direct and 11 of the strains from pine were taken at approximately the same time from the same nursery in Michigan by Mr. Glenn G. Hahn; despite the fact that these were the most recently isolated of the strains used, nearly all of them proved weak in the inoculations. Of the 17 strains which proved the weakest (out of 35), all but 3 were from this Michigan nursery. The 18 strains from other sources (5 from California, 2 from Minnesota, 2 from Kansas, 1 from Wisconsin, 2 from an unknown locality, and 6 from Washington, D. C., representing two coniferous and three dicotyledonous host genera), as shown by solid circles in figure 13, for the most part were rather closely grouped within the more virulent portion of the range. The coefficient of variability in the survivals allowed by the 35 *Pythium debaryanum* strains is 39±3.6 per cent, while for the smaller number of original strains of *Corticium vagum* in experiments 71 and 72 it is 63±9.7 per cent. It is evident from figure 13 that if there had not been a disproportionately larger number of strains from the Michigan nursery the variability of the *P. debaryanum* strains would have been much less than 39 per cent. The number of strains was, of course, altogether insufficient for either fungus to represent adequately a population as immense as the total number of strains of either of these omnipresent species. The above data, however, contain the only available information of which the writer is aware on variation in the virulence of different strains of *P. debaryanum.*

The evidence as a whole, both from the results shown in figure 13 and the experience with 6 other strains which were not used in the experiments on which figure 13 was based, lead the writer to believe that most strains of *Pythium debaryanum* taken from lesions in plants are ordinarily likely to prove rather virulent parasites on pine seedlings. It further appears that the variation in virulence between the different strains of *P. debaryanum* on pine seedlings is less than the variation in strains of *Corticium vagum.*

PYTHIUM INOCULATIONS ON UNHEATED SOIL.

Inoculations with *Pythium debaryanum* were made in western Kansas on a fine sand containing little humus after treating the soil with acid followed by lime. Commercial sulphuric acid was applied at the rate of 14.8 c. c. per square foot of bed, followed two days later by 25.5 grams of air-slaked lime raked into the soil (0.16 liter of acid and 0.274 kg. of lime per square meter). The acid was diluted before applying with 256 volumes of water. The seeds were sown in drills, and inoculum was placed in the drills at the time of sowing. Each unit involved approximately 11 linear inches of drill, and all

received equal quantities of seed. Three strongly parasitic strains of Pythium were used, and a total of 12 units of jack pine and an equal number of western yellow pine was inoculated with 12 interspersed units of each species as controls. The mean results are as follows:

Pinus banksiana.—Inoculated plats: Emerged, 64.2±4.9; died during the next 17 days, 25 per cent. Control plats: Emerged, 85.5±3.6; died during the next 17 days, 13 per cent.

Pinus ponderosa.—Inoculated plats: Emerged, 34.6±1.8; died during the next 9 days, 39 per cent. Control plats: Emerged, 45.4±1.3; died during the next 9 days, 25 per cent.

The difference in emergence apparently due to the inoculation is for the first species three and one-half and for the second nearly five times its probable error. While, of course, 12-unit means are insufficient to allow the calculation of entirely reliable probable errors, they give some idea of the amount of variability of the results and the confidence which can be given them. It is impossible to give any such expression applying directly to the damping-off percentages and their differences, for the reason that averages for this item have been made in the writer's work not by averaging the percentages for the individual units but by totaling all the seedlings and the dead seedlings on the plats to be averaged and recalculating the percentage from these figures. This seems the only safe method, as otherwise units in which germination is low by accident or by the action of parasites will be given an influence on the resultant mean entirely disproportionate to the number of seedlings which they contain. Average values for damping-off obtained by this method and by the method of averaging the percentages of the individual plats or pots are often very different; it not uncommonly happens that the units in which germination is lower than the average also have especially high damping-off percentages, both phenomena being caused by an unusual activity of parasites. In such case to average the percentages themselves usually gives a higher damping-off figure than to total the seedlings for the different units and redetermine the percentage, and the latter practice is considered the better. In the present case the differences in the damping-off percentages obtained by the two methods are not great. The figures obtained by averaging the percentages of the ultimate units are as follows:

Pinus banksiana.—Inoculated, loss 30.9±5.0 per cent; controls, loss 13.2±2.8 per cent.

Pinus ponderosa.—Inoculated, loss 40.0±5.1 per cent; controls, loss 24.1±3.3 per cent.

The differences between the inoculated and control plats in damping-off percentage were for the first species a little over and for the second a little under three times their indicated probable errors.

The results in general make it appear that the Pythium was able to kill some pines both before and after their appearance above the soil surface on the soil treated with the acid and lime. The control in this experiment did not receive the nutrient substratum added with the Pythium inoculum, but an experiment run under the same conditions at nearly the same time, in which seven strains of hyphomycetes with the same substrata entirely failed to decrease survival, indicates that the rice subtratum was not in itself the cause of the observed result. The rather weak action of the Pythium in these experiments stands out in sharp contrast to the results with *Corticium vagum* in the same experiments, practically all emergence being prevented by most of the Corticium strains used, some of which had proved less active than Pythium in tests on autoclaved soil.

In a soil in Nebraska, somewhat similar but with more humus, 5.5 c. c. (three-sixteenths fluid ounce) of sulphuric acid per square foot applied in solution at the time of sowing had been found greatly to decrease damping-off. In different parts of beds treated with acid from 10 to 17 days earlier, 96 plats, each 3 inches square, were laid out, and each plat was inoculated at the center. Interspersed with these were 96 plats set apart as controls. Emergence had already begun at the time of inoculation. Jack pine, red pine, and Corsican pine were the hosts, and three Pythium strains of known parasitism, growing in pieces of prune agar the size of peas, constituted the inoculum. The damping-off after emergence was less than 1 per cent higher for the inoculated plats than for the controls. Even such a light inoculation would probably have given some results in autoclaved soil, so the experiment indicates, as would be expected, that this acid-treated soil was less favorable for *Pythium debaryanum* than steamed soil.

On pots containing entirely untreated soil the following series of inoculations were made at the time of sowing the seed:

Inoculation at one point in each pot:

Experiment 25. Jack and western yellow pine, 1 pot of each inoculated; survival 13 days after emergence slightly greater in both than in the six controls.

Experiment 27. Jack pine, 73 pots, 27 controls; average emergence, 59 in inoculated pots and 56 in controls; damping-off, 39 per cent in inoculated pots and 37 per cent in controls.

Experiment 29. Jack, Corsican, and western yellow pine, 112 plats inoculated just as emergence commenced instead of at seed sowing, as in other cases, and 112 controls alternating with them; damping-off was less in the inoculated plats than in the controls.

Experiment 31. Jack pine, 8 pots inoculated, 8 controls; inoculated, emergence 33 per cent, damping-off 13 per cent, survival 198; controls, emergence 38 per cent, damping-off 26 per cent, survival 196.

Experiment 58A. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 59 per cent, damping-off 32 per cent, survival 40; controls, emergence 51 per cent, damping-off 12 per cent, survival 45.

Inoculations at two points in each pot:

Experiment 26A. Jack pine, 3 pots inoculated, 4 controls; inoculated, emergence 29 per cent, as compared with 39 per cent in the controls; subsequent damping-off the same in both.

Inoculations at four points in each pot:

Experiment 58B. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 51 per cent, damping-off 10 per cent, survival 46; controls, emergence 43 per cent, damping-off 22 per cent, survival 34.

Experiment 59A. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 55 per cent, damping-off 2 per cent, survival 54; controls, emergence 50 per cent, damping-off 8 per cent, survival 46.

Of these experiments, No. 29 was in the original fine sandy soil of a nursery in Nebraska in which Pythium is commonly found native and damping-off losses are usually heavy. Experiments 58A and 59 were conducted on soil from the same source which had been kept dry in the laboratory for five years; experiments 25, 27, 31, and 58A were on greenhouse mixtures of sand and soil. In experiments 31, 58A, 58B, and 59 parallel inoculations were made on autoclaved portions of the same soil, with definitely positive results in three of the four cases. In the heated soil the results were positive, not only because of smaller losses in the controls but because the losses in the inoculated pots were actually heavier in the sterilized soil than in that untreated.

Inoculations broadcast:

Experiment 31. Jack pine, 8 pots inoculated, 8 controls; inoculated, emergence 31 per cent, damping-off 39 per cent, survival 129; controls, emergence 38 per cent, damping-off 26 per cent, survival 196.

Experiment 59. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 58 per cent, damping-off 22 per cent, survival 45; controls, emergence 44 per cent, damping-off 2 per cent, survival 43.

Even with these broadcast inoculations the results on untreated soil were too indefinite to allow the drawing of positive conclusions. In both experiments much heavier losses than these resulted from inoculations on steamed soil. It is evident that experiments on sterilized soil do not always show what can be expected on ordinary soil. The same thing is indicated by the results of Edgerton with tomato wilt (36).

CONCLUSIONS AS TO THE PARASITISM OF PYTHIUM DEBARYANUM.

Pythium debaryanum has been found in low-altitude nurseries in all the species of conifers from which a serious effort has been made to obtain it, and its parasitism has been indicated in autoclaved soil on all of the conifers on which inoculation has been attempted. Therefore, although the work reported has been limited to a relatively small number of hosts, it seems likely that it will be found able to cause damping-off in most of the species of the Abietoideæ which suffer seriously from the disease. Just how active as a parasite it is

under ordinary nursery conditions is yet to be proved. The results in inoculations on disinfected soil, together with the frequency with which the fungus has been isolated from seedlings in the nurseries, lead the writer to believe that it is an important cause of disease in the seed beds. Further experiments on unheated soil, however, are considered desirable.

RHEOSPORANGIUM APHANIDERMATUS.

CULTURAL STRAINS.

A culture of a parasite on radishes and sugar beets, described by Edson (39) under the above name, was obtained from him, and another strain, shown by Edson's records to be a subculture from the same original strain, was furnished by the department of plant pathology of the University of Wisconsin. In parallel cultures on solid media this fungus proved in many ways remarkably like *Pythium debaryanum*, reacting in practically the same way to the different media on which it was grown both in relative growth rate and in spore production. Mycelium, chlamydospores, oogones, antheridia, and oospores are not recognizably different from those of *Pythium debaryanum*. The oospores have seemed on the whole slightly larger and the mycelium a little more inclined to aerial growth than most of the *Pythium debaryanum* strains, but neither difference was sufficient to have diagnostic value. Swellings of the hyphæ occurred at points in contact with glass, just as with *Pythium debaryanum* (Pl. I, figs. 5 to 7).

In liquid cultures the Rheosporangium was readily distinguished from Pythium by the formation of the presporangia described by Edson. Autoclaved cylinders of turnip, 15 to 20 mm. long, cut with a 5-mm. cork borer, proved convenient bases for growth of both Rheosporangium and Pythium in water culture and quite as satisfactory as sterilized beet seedlings. Presporangia were also produced in autoclaved soil, and in a single lot of corn-meal agar they were formed abundantly in the agar in Petri dish cultures. In none of the writer's cultures, either with flies, sugar-beet seedlings, or turnip cylinders as nutrient bases, were mature escaped sporangia or swarm spores commonly produced.

The Rheosporangium was not obtained in any of the numerous cultures made from coniferous seedlings or from seed-bed soil.

INOCULATION EXPERIMENTS.

The Rheosporangium cultures above referred to, strain 229 furnished by Dr. Edson and strain 351 received from the University of Wisconsin, were tested on pine and red-beet seedlings, with parallel inoculations with *Pythium debaryanum*. The results appear in Table VI.

TABLE VI.—*Results of parallel inoculation with Rheosporangium aphanidermatus and Pythium debaryanum on pine seedlings in autoclaved soil.*

Experiment number, host, and inoculating fungus.[a]	Number of pots.	Results.		
		Emerged (per cent of seed).	Damping-off (per cent).	Survival (per cent of seed).
No. 30, Pinus ponderosa:		*Per pot.*	*Per pot.*	*Per pot.*
Rheosporangium, strain 229	5	23	3	22
Pythium, 2 strains	5	14	38	9
Controls	5	20	22	16
No. 31, Pinus banksiana:				
Rheosporangium, strain 229	5	45	13	40
Pythium, strain 225	10	12	44	7
Controls	25	43	5	41
		Per 5-pot unit.		*Per 5-pot unit.*
No. 58, Pinus banksiana:				
Rheosporangium, strain 229	5	46	2	45
Pythium, 8 strains	40	2.6	50	1.3
Controls	10	78	0	78
No. 59, Pinus banksiana:				
Rheosporangium, strain 229	5	46	11	41
Pythium, 8 strains	40	15	35	10
Controls	10	64	0	64
No. 61, Pinus banksiana:				
Rheosporangium, strain 351	20	16	36	10
Pythium, 2 strains	20	2	57	1
Controls	20	60	2	59
No. 61, Pinus banksiana and beets in same pots:				
Pines / Beets } Rheosporangium, strain 351	5	1 / 70	(b) / 88	(b) / 8
No. 61, beets alone:				
Rheosporangium, strain 351	5	43	72	12
No. 62A, beets:				
Rheosporangium, strain 229	15	89	1	88
Rheosporangium, strain 351	4	42	35	27
Pythium, 2 strains	20	12	83	2
Controls	11	86	0	86
No. 62A, beets:				
Rheosporangium, strain 229	5	50	20	40
Rheosporangium, strain 351	5	c 27	78	c 6
Controls	5	c 77	1	c 76
No. 62A, beets and Pinus banksiana in same pots:				
Pines / Beets } Rheosporangium, strain 229	5	64 / 42	14 / 22	55 / 33
Pines / Beets } Rheosporangium, strain 351	5	46 / 27	33 / 78	31 / 6
Pines / Beets } Controls	5	81 / 67	0 / 0	81 / 57
No. 62B, Jack pine: [d]				
Rheosporangium, strain 229	2	58	14	50
Rheosporangium, strain 351	2	53	10	48
Pythium, strain 258	2	10	100	0
Controls	3	82	0	82
No. 66, Jack pine:				
Rheosporangium, strain 229	5	63	9	58
Rheosporangium, strain 351	5	80	52	39
Pythium, 47 strains and substrains	235	43	33	29
Controls	25	75	14	64
No. 67, Jack pine:				
Rheosporangium, strain 229	5	107	0	107
Rheosporangium, strain 351	5	88	6	83
Pythium, 47 strains and substrains	235	51	26	38
Controls	23	87	5	83
No. 68, Red pine:				
Rheosporangium, strain 229	5	105	0	105
Rheosporangium, strain 351	5	124	0	124
Pythium, 47 strains and substrains	235	86	27	63
Controls	18	104	0	104

[a] Location of the inoculum: In experiment 30, at one point at the edge of each pot; in experiment 31, over the entire pot; in all other experiments, over one-quarter the area of each pot.
[b] The breakage of the one seedling not killed while sprouting prevented the determination of results.
[c] Double seed density in these pots; emergence and survival figures halved to allow direct comparison with other units. This high seed density may explain in part the higher loss in strain 351 than in strain 229.
[d] Experiment 62B was conducted at the same time as 62A, but with a different soil.

Table VI shows that in experiments 30 and 67 the loss was less in the Rheosporangium pots than in the controls and that in experiment 68 the results were entirely negative, while in the remaining seven

experiments the losses were heavier in the Rheosporangium pots. Especially in experiments 61 and 62A the evidence indicates very strongly that both germination loss and subsequent damping-off of the seedlings which come up can be caused by inoculation with Rheosporangium on jack pine under favorable inoculation conditions. It is, however, obvious that in all of the experiments the parallel inoculations with *Pythium debaryanum* gave much more positive results. The Pythium was active under conditions in which the Rheosporangium gave no evidence whatever of parasitic capacity. It furthermore appears that the two strains of Rheosporangium, though probably identical originally, differed in virulence at the time of their comparison in these experiments. The greater virulence of strain 351 was quite distinct in most of the comparative tests on beets as well as on pines. The possibility that the original culture was really a composite of two or more strains, of which different ones survived in the subcultures kept at Washington and Madison, respectively, seems worth considering. Such an accident might also have been responsible for the divergence of Pythium strains 131 and 295 referred to in another section.

Further evidence of the parasitism of Rheosporangium was obtained in inoculations with cultures reisolated from seedlings killed by the original strains in experiment 62. Typical Rheosporangium, identified by presporangium formation, was easily recovered from the damped-off seedlings in pots of pines only, those of beets only, and the pots in which both hosts were sown. The recovery of a virulent Pythium strain from a single one of the pots inoculated with the weaker Rheosporangium shows that despite the absence of disease in the controls a slight amount of contamination did occur. However, the comparative ease with which the Rheosporangium was isolated from seedlings in other pots inoculated with it and the fact that it has never been obtained in the numerous cultures made from controls and from pots inoculated with other organisms leave little room for doubt that the strains isolated were really recoveries of the Rheosporangium used in the original inoculations. The results of reinoculation with these strains are shown in Table VII.

From Table VII and by comparison with Table VI it appears—

(1) That in one experiment each on jack pine and red pine the reisolated Rheosporangium strains gave positive results. In a second experiment on jack pine (No. 67) the difference between the Rheosporangium pots and the controls was not significant.

(2) That, as in Table VI, the Pythium strains used proved on the whole decidedly more parasitic than the Rheosporangium strains. In experiment 66 this is not shown by the percentage of seedlings damped-off, but is sufficiently evident when the germination loss as well as the subsequent damping-off percentage is considered, the survival being here, as in most other cases in which

either of the groups of pots compared is seriously affected by parasites, the most convenient index of the comparative activity of the fungi used. In such a comparison as that between the Rheosporangium pots and the controls in experiment 68 (Table VII), accidental variations in emergence, of course, overshadow the slight effect of the fungus, and the definitely determinable percentage of loss after emergence is the only value which can serve as a basis for any definite conclusion.

TABLE VII.—*Results of inoculations on pine seedlings with initial and reisolated strains of Rheosporangium aphanidermatus compared with parallel inoculations with Pythium debaryanum.*

Experiment number, host, and inoculating fungus.	Reisolation source.	Number of pots.	Number of strains.	Results.		
				Emerged (per 5-pot unit).	Damping-off (per cent).	Survival (per 5-pot unit).
No. 66, Pinus banksiana:						
Rheosporangium—						
Strain 229	Edson from beet	5	1	63	9	58
Strain 351	do	5	1	80	52	39
Strains 403 and 404	Strain 229 from beet	10	2	78	43	44
Strains 405, 406, and 407	Strain 351 from beet	15	3	63	43	36
Strains 417, 430, and 433	Strain 351 from pine	15	3	72	42	41
Average		50	10	70±2.7	40	42±3.8
Controls		25		75	15	64
Pythium, average		235	47	43	33	29
No. 67, Pinus banksiana:						
Rheosporangium—						
Strain 229	Edson from beet	5	1	107	0	107
Strain 351	do	5	1	88	6	83
Strains 403 and 404	Strain 229 from beet	10	2	91	8	84
Strains 405, 406, and 407	Strain 351 from beet	15	3	92	4	88
Strains 417, 430, and 433	Strain 351 from pine	15	3	83	3	80
Average		50	10	90±2.4	4	86±2.9
Controls		23		87	5	83
Pythium, average		235	47	51	26	38
No. 68, Pinus resinosa:						
Rheosporangium—						
Strain 229	Edson from beet	5	1	105	0	105
Strain 351	do	5	1	124	0	124
Strains 403 and 404	Strain 229 from beet	10	2	102	1	101
Strains 405, 406, and 407	Strain 351 from beet	15	3	105	5	100
Strains 417, 430, and 433	Strain 351 from pine	15	3	100	3	97
Average		50	10	105±2.3	2	102±2.5
Controls		18		104	0	104
Pythium, average		235	47	86	27	63

A frequency graph based on the survivals of the 50 individual pots inoculated with Rheosporangium in experiment 68 yields a rather interesting asymmetrical curve (fig. 17). The shape of the curve is taken as indicating that in a large number of the pots the inoculation produced no effect, while in the smaller number of pots in which the inoculation apparently "took," the loss was rather heavy. This is a rather common phenomenon in inoculations which are only partly successful, part of the pots being free or practically free from loss, while others are nearly cleaned out. It will be seen again in

figure 18. This suggests, further, that part of the lack of activity was due to the failure of the fungus to maintain itself vigorously in the soil till the pines reached a stage of sprouting in which they could be readily attacked. Direct inoculations after the seed starts to sprout are therefore desirable to supplement the experiments reported. The survivals in the controls did not show any such asymmetrical distribution.

While the Rheosporangium has given rather definite evidence of parasitism on *Pinus banksiana* under favorable conditions, the activity of the strains available has been much less than that of the *Pythium debaryanum* strains. In view of the fact that the fungus has not so far been isolated from pine it can be concluded to have no general importance in pine seed beds. Its very rapid growth on prune agar makes it very easy to isolate when present.

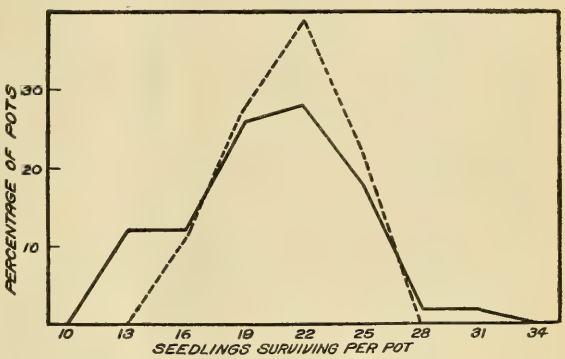


FIG. 17.—Diagram showing the results of inoculation of *Pinus resinosa* seedlings with *Rheosporangium aphanidermatus*, as indicated by the number of seedlings surviving in inoculated pots (solid line) and control pots (broken line). The shape of the curve for the inoculated pots is taken as indicating that a large proportion of them were entirely unaffected by inoculation, while those which were at all affected suffered considerably. This is a frequent result in inoculations with weak parasites added at the time of sowing the seed.

PHYTOPHTHORA SPP.

Phytophthora fagi R. Hartig has been commonly reported as the cause of death of seedlings of various plants in Europe, including conifers and herbaceous plants as well as beech (5, 8, 15, 55, 56, 57, 59, 73, 104.) It has been grouped with the rather indefinite *Phytophthora omnivora* and with *P. cactorum*, the enemy of cactus, ginseng, and other plants. Wilson (147, p. 54) considered it distinct, but Rosenbaum (114), in his biometric comparison of *Phytophthora cactorum* and a single strain of *P. fagi*, failed to find significant morphological differences. If *P. fagi* is even physiologically different from the American strains of *P. cactorum*, its introduction into the United States is to be guarded against. There is certainly no fungus in the United States causing the damage to coniferous seedlings which European reports have attributed to *P. fagi* there. As *P. fagi* attacks roots, it presumably can be carried in soil as well as on plant parts.

A test made on jack pine with a culture of *Phytophthora cactorum*, furnished by the department of plant pathology of Cornell University, resulted negatively. At the time of sowing the seed three pots were inoculated with cultures on nutrient agar inserted at several points in each pot. After emergence additional fragments of prune-agar cultures were placed in contact with the seedlings, and they were

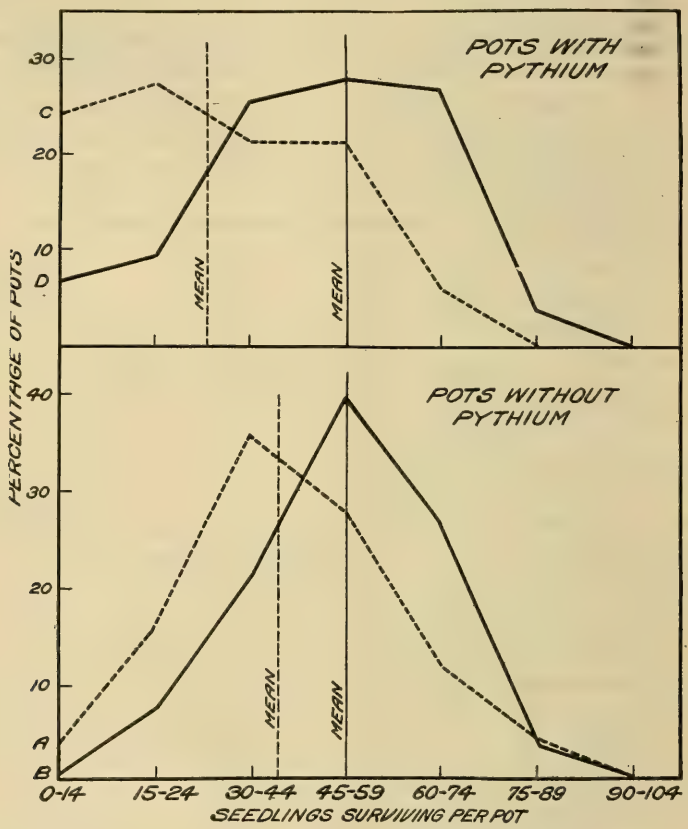


FIG. 18.—Frequency of pots with different numbers of surviving seedlings of *Pinus banksiana*, inoculation experiment No. 31. The solid lines represent pots to which cultures of saprophytic organisms were added. The broken lines are based on pots to which no saprophytes had been added. The solid lines are based on 78 pots in the upper graph and 80 pots in the lower one; the broken lines on 33 pots in the upper and 25 pots in the lower graph. *Pythium debaryanum* was added just after sowing the seed at a single point in each pot represented by the two upper lines. Cultures of saprophytes were applied broadcast two days before the Pythium inoculations were made.

sprayed with a spore suspension. The pots were covered with glass to increase atmospheric moisture, and the seedlings were occasionally sprayed with an atomizer. The soil was an autoclaved mixture in which simultaneous inoculations in a different room with Pythium and Corticium proved successful. The failure of the Phytophthora may possibly have been due to the lower temperature at which the pots inoculated with it were kept (15° to 20° C.).

A species of Phytophthora was isolated by Mr. R. G. Pierce from damped-off *Pinus resinosa* in Minnesota and used in four inoculation experiments, the results of which appear in Table VIII. In the first of these experiments unboiled water was used on the pots, and mice obtained access to the pots of the second test. Probably as a result of these things infection occurred in the controls in both cases, and the results were inconclusive; in the later experiments these two sources of infection were eliminated, and in experiments 68 and 72B the controls were free from disease. Parasitic activity was indicated rather strongly in experiments 68 and 72 (on *P. resinosa* and *P. banksiana*) and to a certain extent in experiment 66. In experiment 67 it was evident that the Phytophthora was nearly or entirely inactive. Comparison of the results in experiments 66 and 68 with the results from inoculations with *Rheosporangium aphanidermatus* in the same experiments (Table VII) suggests that the Phytophthora may be better able to attack the pine from which it was isolated than the Rheosporangium, while the latter fungus caused considerably more destruction to *Pinus banksiana* than the Phytophthora. Comparison of the results in the pots inoculated with Phytophthora and those inoculated with *Pythium debaryanum* in all the experiments indicates that the Phytophthora strains used were less virulent than most of the strains of *P. debaryanum* and very certainly less destructive than the most active strains of either *P. debaryanum* or *Corticium vagum*. This species of Phytophthora has been reisolated from damped-off *Pinus ponderosa* in experiment 72.

Direct inoculations of the stems of seedlings of *Pinus resinosa* soon after they emerge from the soil have so far confirmed the lack of parasitism of *Phytophthora cactorum* and of the cultures of *Phytophthora* sp. grown by the writer. The identity of this species has not yet been determined. It is able to grow only about one-fourth as rapidly as *Pythium debaryanum* on the medium which has been used for isolation and may therefore be more common in the seed beds than the small number of isolations by the planted-plate method would indicate. However, its oospores, larger and darker than those of *Pythium debaryanum* (usually over 20 μ in diameter), should have been recognized in the routine microscopic examination of planted-plate cultures had this species been frequently present, even if it had not grown fast enough to get out ahead of the other organism and allow isolation. It is not believed that it is common enough in pine seed beds to be of importance, even if other strains should be found more virulent than those which have been available.

MISCELLANEOUS PHYCOMYCETES.

A fungus, apparently referable to the somewhat indefinite *Pythium artotrogus* (Mont.) De Bary, was isolated by Mr. Glenn G. Hahn from *Pinus resinosa* in Michigan and from damped-off *Pinus bank-*

siana in pots of autoclaved soil which had received tap water at Washington, D. C. It agreed both in the appearance and measurements of its spiny oogones and smooth oospores with *Pythium artotrogus* (*P. hydnosporus*) as described and figured by Butler (23). In addition to the spores which Butler describes, there appeared in apparently pure prune-agar cultures of different strains bodies with smooth walls, of somewhat irregular ovoid outline, and mostly larger than either oospores or oogones. They are very much less abundant than the sexual spore forms. Their greatest diameter varied from 11 μ to over 40 μ. The germination of these bodies was not observed. Efforts to induce the fungus to produce swarm spores by growing them in liquid nutrient media and transferring them to pure water were unsuccessful. This failure to produce zoospores is further indication of the identity of the fungus with that described by Butler, who says that asexual reproduction is unknown.

The strain from Michigan was a rather weak growing organism, difficult to maintain in tube cultures without rather frequent transfers. Its parasitic activity in the experiments reported in Table VIII is nil or negligible. Because of the poor seed and small number of seedlings involved in experiment 72B, the percentage of damping-off there given means only a single seedling dead. The Washington strains, on the other hand, though evidently not strong parasites, did apparently cause the death of a number of seedlings. The best evidence of this is in experiment 68, in which there was damping-off in each of the five 5-pot units containing the Washington strains and none in any of the 18 control pots. The available strains were less active not only than *Pythium debaryanum*, but less than the Rheosporangium and Phytophthora strains used. The fungus is believed to be a potential parasite on pine seedlings, but not one of any general importance. What is probably the same fungus had appeared in the writer's cultures from western nurseries in conjunction with *P. debaryanum*, but not commonly, and it had not been isolated. While its growth rate is only about half that of *P. debaryanum* on prune agar, it is nevertheless so much faster than that of many fungi that it should have been more often obtained in culture were it at all common in damped-off seedlings.

Another fungus, presumably an oomycete but producing only chlamydospores in the writer's cultures, was obtained from damped-off olive seedlings furnished by Prof. W. T. Horne and from soil direct, both at Berkeley, Calif. The fungus is apparently the same as one which has been occasionally seen in cultures from pine seedlings in the Middle West, but had not before been isolated. The hyphæ are ordinarily nonseptate, and the growth on corn-meal agar is superficially much like that of *Pythium debaryanum*, but with greater tendency toward local zonation and aerial growth and less

than half as rapid. Chlamydospores are mostly intercalary, at first subspherical, soon becoming polygonal, and after a few days they shrivel and exhibit thick, angular walls. In size the unshrunken spores usually lie between 8 and 12 μ in diameter, but bodies as large as 20 μ occasionally occur. Antheridia have not been observed, and the shriveled bodies are not believed to be oospores, though the observations made have not been sufficient to exclude such a possibility. No other spore form was obtained in water culture, using various nutrient substrata. In inoculation the strain from olive (the "undetermined Phycomycete" included in Table VIII) has given negative or nearly negative results in three inoculation tests in which other fungi gave positive results. In a test not included in the table, in which *Pinus ponderosa* was the trial host, damping-off was slightly higher in the inoculated pots than in the controls, but the difference was apparently due to accidental infection with Botrytis and *Pythium debaryanum*. As all the seedlings in pots inoculated with *P. debaryanum* in this additional experiment were killed, the relative unimportance of this strain of the small-spored fungus was further indicated. An additional test of both the olive strain and the strain from soil was made by inoculating seedlings of *Pinus banksiana* and *P. ponderosa* growing on filter paper in Petri dishes. Some of these were kept wet with water, some with an inorganic culture solution, and some with the inorganic solution plus peptone and dextrose. Agar cultures were applied directly to the seedlings. The seedlings inoculated with the small-spored fungus remained alive as long as the control seedlings, while parallel inoculations with *Pythium debaryanum* resulted in the early decay of the seedlings.

TABLE VIII.—*Results of inoculations with miscellaneous oomycetes on pines in autoclaved soil at the time of sowing.*

[In all the experiments included in this table, the inoculum consisted of fragments of agar cultures distributed with the seed at one side of each pot over about one-fourth of the pot area. The controls received sterile agar in the same way.]

Experiment number, host, and inoculating fungus.	Number of pots.	Results.		
		Emerged.	Damping-off.	Survival.
No. 66, Pinus banksiana:		*Per 5-pot unit.*	*Percent.*	*Per 5-pot unit.*
Phytophthora sp.—				
Strain 358	5	70	30	49
Strain 372	5	75	28	54
Strain 375	5	94	16	79
Pythium artotrogus (?), Michigan strain	4	115	14	99
Undetermined Phycomycete	5	83	9	76
Controls	25	75	−14	64
No. 67, Pinus banksiana:				
Phytophthora sp.—				
Strain 358	5	96	1	95
Strain 372	5	88	3	85
Strain 375	5	99	0	99
Pythium artotrogus (?), Michigan strain	5	102	2	100
Undetermined Phycomycete	5	98	0	98
Controls	23	87	5	83

TABLE VIII.—*Results of inoculations with miscellaneous oomycetes on pines in autoclaved soil at the time of sowing*—Continued.

Experiment number, host, and inoculating fungus.	Number of pots.	Results.		
		Emerged.	Damping-off.	Survival.
No. 68, Pinus resinosa:		*Per 5-pot unit.*	*Per cent.*	*Per 5-pot unit.*
Phytophthora sp.—				
Strain 358	5	104	7	97
Strain 372	5	109	18	89
Strain 375	5	98	5	93
Pythium artotrogus (?), Michigan strain	5	121	0	121
Pythium artotrogus (?), Washington, D. C.—				
Strain 821	5	122	1	121
Strain 823	5	120	9	109
Strain 831	5	96	5	91
Strain 832	5	110	6	103
Strain 833	5	94	1	93
Undetermined Phycomycete	5	84	2	82
Controls	18	104	0	104
No. 72A, Pinus resinosa:		*Per 3-pot unit.*		*Per 3-pot unit.*
Phytophthora sp.—				
Strain 372	3	20	35	13
Pythium artotrogus (?), Michigan strain	3	62	0	62
Pythium artotrogus (?), Washington, D. C.—				
Strain 821	2	45	7	42
Strain 831	3	37	0	37
Strain 833	3	40	25	30
Controls	16	35	5	33
No. 72B, Pinus ponderosa:				
Phytophthora sp	3	8	50	4
Pythium artotrogus (?), Michigan strain	3	13	8	12
Pythium artotrogus (?), Washington, D. C.—				
Strain 821	3	11	0	11
Strain 831	2	29	6	27
Strain 833	2	6	0	6
Controls	14	9	0	9

OTHER FUNGI.

Data on the possible relation between various other fungi and the damping-off of conifers have been already summarized by Hartley, Merrill, and Rhoads (68, p. 546–550). *Pestalozzia funerea* on the basis of the experiments of Spaulding (135), *Botrytis cinerea* on the basis of observation and very preliminary inoculations, and *Trichoderma koningi* on cultural evidence only are all believed to be potential causes of damping-off, though not ordinarily important. *Alternaria* sp. is under a certain amount of suspicion on account of its frequent association with the damping-off of conifers, but it has never been used in experiments. *Rhizopus nigricans* (incorrectly reported as Mucor), *Trichothecium roseum*, *Rosellinia* sp. from nursery soil, *Chaetomium* sp. from maple roots, strains of Penicillium and Aspergillus, *Phoma betae*, and *Phoma* spp. are all reported to have been used in inoculations with negative results.

Since the publication of the above summary a preliminary successful inoculation experiment with *Botrytis cinerea* on recently emerged *Pseudotsuga taxifolia* has been found briefly mentioned in an article by Tubeuf (140) on another disease. Further experiments with va-

rious strains of Botrytis, both from conifers and from other hosts (the latter supplied by the departments of plant pathology of the California and New York (Cornell) Agricultural Experiment Stations), have already yielded confirmatory evidence of the parasitism of *B. cinerea.*

While a considerable number of fungi have been considered in the foregoing, it is entirely possible that there are still parasites which have received no consideration and that some of them may perhaps be important. The moist-chamber method of culturing parasites for isolation yields only those which produce spores readily; the planted-plate method is not well adapted to the isolation of slow-growing fungi or bacteria. It is suggested that in further culture work with damped-off conifers an attempt be made to secure slow-growing organisms by dilution plates of teased-up fragments of recent lesions.

RELATIVE IMPORTANCE OF THE DAMPING-OFF FUNGI ON CONIFERS.

The relative importance of the different damping-off parasites is something that has not been thoroughly investigated for any host. The most information on this point is that given by Busse, Peters, and Ulrich (22) for sugar beet. In this case they find the specialized *Phoma betae* distinctly the most important, with *Pythium debaryanum* second and *Aphanomyces levis* third.

Peters (100) apparently considered Rhizoctonia unimportant as a cause of beet damping-off. The opposite was indicated by a small number of cultures by Edson (38) from beet seedlings on Kansas and Colorado soil. These yielded more *Corticium vagum* than any other parasite and no Pythium at all. Johnson (81) states that most of the damping-off of tobacco seedlings is due to *Pythium debaryanum* and *Corticium vagum.* Atkinson (1), speaking for cotton in Alabama, and Sherbakoff (127, p. xcv; 128; 129), speaking for truck crops in Florida, make *Corticium vagum* the important damping-off parasite, with *P. debaryanum* negligible. Horne (oral communication) found the same situation in tobacco seed beds in Cuba. Atkinson (3), in an article on trees, held that many of the cases of damping-off attributed to *P. debaryanum* are in reality due to *C. vagum.* Peltier (98, pp. 336–337) has reported *Rhizoctonia solani* as the cause of damping-off of a large number of plants, recording his observation of the damping-off of seedlings of nearly 50 species of miscellaneous genera and cuttings of 13 different species, all of which he attributes to the Rhizoctonia. He does not state whether in this case he used diagnostic methods likely to detect *Pythium debaryanum* if it had been present.

For the conifers, no very reliable data on relative importance have been published. Numerous European reports emphasize the damage due to *Fusarium* spp., while a smaller number attribute loss to *Phytophthora fagi* or to both. There seems to have been little effort to determine the presence or absence of Corticium or Pythium, so these reports can not be given great weight. Spaulding's evident belief (136) in the importance of Fusarium has more weight, as he was on the lookout for the other fungi; the moist-chamber diagnostic method employed in most of this work was, however, not well adapted to the detection of either one. The same is true of the work of Rathbun (106), in which dilution plates of seed-bed soil were employed. Rankin (105) attributes to *Fusarium* spp. the greatest importance in tree seed beds in this country, with *Pythium debaryanum* and *Rhizoctonia* spp. important in certain cases. Gifford (46) emphasizes the importance of Fusarium, while Clinton (28) apparently found Rhizoctonia (*Corticium vagum*) especially prevalent in the examinations he made.

On the basis of the data presented or summarized in this bulletin, it is believed that of the various organisms which have been connected with damping-off in coniferous seed beds *Pythium debaryanum*, *Corticium vagum*, and *Fusarium* spp. include all of importance. The others, either because of low indicated virulence or infrequent occurrence, and in most cases both, do not seem to merit extensive consideration.

In order to form an idea of the relative frequency of the parasites named above as important, there have been brought together in Table IX the results of the examination of 438 damping-off foci in untreated beds and 304 foci which have appeared in beds which had received various disinfectant treatments. The data are presented by foci rather than by individual seedlings, as was done in the census reported by Busse and his coworkers. Most of the diagnoses were made by planting recently diseased seedlings in plates of solidified prune agar, all the seedlings taken from the same focus, or "patch," of damped-off seedlings being put into the same Petri dish. The resulting growth was in some cases transferred to a tube for later examination, but was usually examined directly in the plate. In a smaller number of foci the seedlings were macerated and examined directly without recourse to culture methods. As *Pythium debaryanum* does not commonly fruit in diseased seedlings of pine or of tobacco (81) and its hyphæ are both difficult to find and not in themselves considered a sufficient diagnostic character, this latter method of examination is not so satisfactory for the determination of Pythium as it is for Corticium, which is easily recognized by its

thick-walled truncate-tipped hyphæ and characteristic branching. A further difficulty in the direct-examination method, unless the seedlings are sectioned, is in distinguishing between Corticium hyphæ which are in the tissues and those outside. The well-known habit of the Corticium of sending hyphæ superficially over the surface of plants which it is not appreciably injuring makes it evident that only hyphæ actually found in the tissues have diagnostic value. Direct microscopic examination is, furthermore, very likely to fail to detect Fusarium. The planted-plate method therefore appears the better of the two, and the results of the culture diagnoses appearing in the lowest two lines of Table IX deserve probably more attention than the total occurring a few lines above, in which the results of direct examination of the seedlings are also included. The high proportion of Corticium reported from the Michigan and Minnesota nurseries is probably due in part to the fact that most of the examinations made there were of the direct microscopic type.

TABLE IX.—*Results of the examination of damping-off foci in coniferous seed beds for Pythium debaryanum, Corticium vagum, and Fusarium spp.*

Grouping.	Untreated beds.				Beds of heated soil.				Beds treated with strong acids.			
	Foci examined.	Number showing—			Foci examined.	Number showing—			Foci examined.	Number showing—		
		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.
By locality:												
Berkeley, Calif.	4	3	1	2	----	----	----	----	5	5	0	2
Manitou, Colo.	22	0	19	0	----	----	----	----	----	----	----	----
Monument, Colo.	34	6	20	13	----	----	----	----	----	----	----	----
Garden City, Kans.—												
Garden City Nurseries	18	4	0	9	14	5	0	7	28	8	2	9
Kansas Nurseries (sand)	20	4	9	7	15	2	0	6	16	9	2	8
Halsey, Nebr.	224	124	45	155	28	10	0	17	99	34	2	61
Cass Lake, Minn.	42	15	21	5	----	----	----	----	1	0	0	0
Dundee, Ill.	4	0	4	1	----	----	----	----	----	----	----	----
East Tawas, Mich.—												
Beal Nurseries (sand)	45	14	33	2	----	----	----	----	1	1	0	0
East Tawas Nurseries	13	11	7	1	----	----	----	----	13	7	6	2
Washington greenhouse	12	3	3	9	7	2	0	3	----	----	----	----
Total:												
Number	438	184	162	204	64	19	0	33	163	64	12	82
Percentage	100	42	37	47	100	30	0	52	100	39	5	50
By diagnostic methods:												
Direct examination—												
Number	156	39	108	25	0	----	----	----	16	6	8	4
Percentage	100	25	69	16	----	----	----	----	100	38	50	25
Planted-plate cultures—												
Number	282	145	54	179	64	19	0	33	147	58	4	78
Percentage	100	51	19	63	100	30	0	52	100	39	3	53

TABLE IX.—*Results of the examination of damping-off foci in coniferous seed beds for Pythium debaryanum, Corticium vagum, and Fusarium spp.*—Con.

Grouping.	Beds treated with formaldehyde.				Beds treated with copper sulphate.				Beds treated with zinc chlorid.				All treated beds.			
	Foci examined.	Number showing—			Foci examined.	Number showing—			Foci examined.	Number showing—			Foci examined.	Number showing—		
		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.
By locality:																
Berkeley, Calif.	----	----	----	----	----	----	----	----	----	----	----	----	5	5	0	2
Manitou, Colo.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Monument, Colo.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Garden City, Kans.—																
Garden City Nurseries	6	0	6	3	1	0	0	1	3	1	0	3	52	14	8	23
Kansas Nurseries (sand)	----	----	----	----	----	----	----	----	----	----	----	----	31	11	2	14
Halsey, Nebr.	34	20	1	24	6	3	0	5	8	0	0	5	175	67	3	112
Cass Lake, Minn.	----	----	----	----	----	----	----	----	----	----	----	----	1	0	0	0
Dundee, Ill.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
East Tawas, Mich.—																
Beal Nurseries (sand)	----	----	----	----	----	----	----	----	----	----	----	----	1	1	0	0
East Tawas Nurseries	8	5	4	0	6	5	3	3	5	3	0	2	32	20	13	7
Washington greenhouse	----	----	----	----	----	----	----	----	----	----	----	----	7	2	0	3
Total:																
Number	48	25	11	27	13	8	3	9	16	4	0	10	304	120	26	161
Percentage	100	52	23	56	100	62	23	69	100	25	0	63	100	39	9	53
By diagnostic methods:																
Direct examination—																
Number	8	5	4	0	5	4	2	2	5	3	0	2	34	18	14	8
Percentage	100	63	50	0	100	80	40	40	100	60	0	40	100	53	41	24
Planted-plate cultures—																
Number	40	20	7	27	8	4	1	7	11	1	0	8	270	102	12	153
Percentage	100	50	18	68	100	50	13	88	100	9	0	73	100	38	4	57

The data on the different nurseries do not allow any generalizing on the basis of locality except to say that all of the fungi seem quite generally distributed in the Lake States and Great Plains region. In general, it appears that the Fusaria as a group are more common than either of the other fungi; as they grow more slowly than either the Pythium or the Corticium, they were probably rather more common relatively than even the plate-culture method indicated. It also appears that the Pythium occurred in more foci than the Corticium in the beds examined. Further culture work, perhaps by the method of dilution plates of fragments of lesions, seems desirable, especially in the East and the Northwest, regions in which there are large coniferous nurseries and in which nothing like a parasite census has been attempted. Observations on the type of focus occurring in most of the nurseries in the Rocky Mountains leads the writer to believe that Corticium will be found especially important there.

While the data on the fungi in foci in disinfected beds are insufficient to serve as a basis for much in the way of conclusions for any individual treatment, they in general agree with the assumption, which knowledge of the fungi would favor, that Corticium is the

most easily controlled by soil disinfection (see the bottom line in the last four columns of Table IX). Its poor adaptation for aerial dissemination would lead one to expect to find it seldom in beds treated with efficient disinfectants. The entire absence of Corticium in heated soil therefore seems somewhat significant. The rather high Corticium yield in the formaldehyde plats is of some interest in view of the reported inefficiency of formaldehyde in destroying *Corticium vagum* on potato tubers (48, 50). As will be noted from the data given, more than one suspected parasite was often found in what appeared to be a single focus. This was probably in some cases due to independent foci being nearly concentric; it also in some cases undoubtedly means that one of the organisms found was only secondary. In the beet-seedling cultures by Busse and his associates, individual seedlings yielded two or more potential parasites in 100 of their nearly 1,300 examinations. It not infrequently happened in the work on pine seedlings that no fungus recognized as a likely parasite could be isolated. This was especially true in plate cultures when Rhizopus or Trichoderma happened to be abundant, as both are very fast growing and often suppress parasites. This is an additional reason for the development of some method as a dilution plate of lesion fragments for diagnosing damping-off.

Even an accurate and complete census of the organisms present in the different foci could not be directly interpreted in terms of relative importance. None of the parasites so far used in inoculation have been vigorously parasitic under all conditions. Of both *Corticium vagum* and *Pythium debaryanum* some strains, microscopically indistinguishable from the others, are very weak as parasites. Only part of the Fusarium species are parasitic on pine, and data showing which are and which are not parasitic are known for only a very few. There is therefore no fungus which can be said positively to be the cause of any particular damping-off "patch" simply because it was found in some of the dead seedlings in the patch. In an occasional exceptional case, such as the large Corticium patch in figures 7 and 8, there is such a vigorous growth of the fungus that its predominance is undoubted, but such cases are rather rare. A census throws light on the importance of the different fungi, but can be interpreted only in the light of inoculation results.

For Pythium and Corticium the inoculation data do not permit any simple comparison between the two, for the reason that neither is uniform. Each has strains of high virulence and strains having practically no effect on pines. In the inoculations in autoclaved soil at sowing time the strongest strains of *Corticium vagum* have on the whole caused more damage than any of the Pythium strains, but, on the other hand, there has seemed to be a higher proportion of very

weak strains of *C. vagum* than in the case of Pythium. In inoculations on *Pinus banksiana* and *P. ponderosa* in Kansas sand treated with acid followed by lime, the average Corticium was very much more destructive than even the strongest Pythium strains, allowing practically no germination in most cases. On the other hand, in experiments in which the inoculum was applied directly to *Pinus resinosa* and *P. ponderosa* seedlings, either immediately after germination or after the older parts had become resistant, the Pythium has been the more effective. The inoculation evidence so far available justifies so nearly equal emphasis on the two that it can practically be eliminated from the calculations. It is the writer's opinion that the Corticium strains are probably rather less virulent on the average than the Pythium strains, but perhaps better able to maintain themselves and spread from one seedling to another in most soils. The evidence of Table IX that the Corticium seemed less frequent in the damping-off foci is more or less counterbalanced by the apparent larger size of many of the disease patches which it seems to cause in the seed beds. Nearly all the large clean areas such as are shown in figures 7 and 8 have been found to contain abundant Corticium hyphæ. The evidence on the whole seems to indicate a very nearly equal importance for the two fungi. The Pythium is probably somewhat the more important for the stations at which most of the cultures in Table IX were made, but the Corticium has received more emphasis from other observers in this country and is indicated by the writer's observations to be more important in the western mountains than any other damping-off fungus.

The inoculation evidence for *Fusarium* spp., though less complete than for Corticium and Pythium, is nevertheless rather helpful in indicating their importance rating. None of those so far tested in inoculations at sowing have shown the destructiveness of the average strains of Pythium or of the stronger strains of Corticium; while this is only in part a test of virulence and in part a test of the ability of the fungus to grow saprophytically in the soils used, the indication is that no one Fusarium species is the equal in destructive capacity of either *Corticium vagum* or *Pythium debaryanum*. However, when all of the Fusarium species which occur in the seed beds are considered, the group as a whole may prove quite as important or even more important than either of the other two fungi. The data already at hand rather definitely indicate considerable importance for all three.

DAMPING-OFF FUNGI AS CAUSES OF ROOT-ROT AND LATE DAMPING-OFF.

As has been already stated, root-rot, often with frequent recovery, has been commonly observed in seedlings several weeks old. It has been especially common in the vicinity of old damping-off foci in

which *Corticium vagum* appeared to be the active parasite, but beyond this indication of the causal relation of *C. vagum* it was not known which of the damping-off fungi were able to attack the roots of seedlings too old to be killed by damping-off. To throw light on this point, seedlings of *Pinus ponderosa* and *P. resinosa* grown in autoclaved soil in the greenhouse and approximately 1½ months old were inoculated with different fungi. There had been a certain degree of early damping-off in these pots, but it had apparently ceased before the inoculations were made. The inoculum used consisted of cultures on rice introduced through the drainage holes at the bottoms of the pots. The strains of *Pythium debaryanum* and *Corticium vagum* used were the ones which had given maximum results in earlier inoculation experiments at the time of sowing. The strain of *Fusarium ventricosum* was the only one available, and the *Fusarium moniliforme* strains were all of approximately equal virulence, the three used having given as much evidence of parasitism as any of the strains of this species in the earlier damping-off experiments. Three pots of each pine were inoculated with each strain. Two 3-pot units of each pine were set aside as controls and inoculated with sterile rice. In addition, three pots of each pine were kept in the same bench without the addition of any inoculum, for comparison with the controls with rice. The results of this experiment, taken a month after the inoculations were made, with the seedlings averaging 2½ months old, appear in Table X. The roots of the living seedlings were washed out carefully with water to permit examination.

The results in so far as they indicate root-rot of the oldest seedlings are best shown by the figures in columns 4 and 5. These seedlings were so far advanced that the fungi had not been able to kill them, and nearly all would probably have recovered if they had not been dug up. It will be noted from column 4 of Table X that a considerable portion of the *Pinus ponderosa* seedlings with root-rot had already made their recovery apparent by pushing out adventitious roots above the decayed portion at the time they were examined.

For *Fusarium ventricosum* there was only the merest indication of ability to attack pine roots at this stage. For *F. moniliforme* the evidence is somewhat better, more pots being included and the difference in healthy-topped seedlings with injured roots between the inoculated pots and the controls being approximately twice its indicated probable error for each species. The percentage of root-injured seedlings in the *Pythium debaryanum* pots exceeded that in the controls in each species by between three and four times the probable error of the difference, while the difference in percentage between the *Corticium vagum* pots and the controls is approximately four times its probable error in the case of *Pinus ponderosa* and five and one-half times its probable error in the *Pinus resinosa* pots. The

weak point in the results is, of course, the insufficiency of the 6-pot and 9-pot groups as bases for probable-error determination. The indicated relative ability of these different fungi to cause root-rot is about the same as their relative ability to cause the damping-off of sprouting seed and young seedlings, as indicated by the results of the earlier experiments in which inoculations were made at the time of sowing. The fact that only the very strongest available strains were used and that the pots were rather heavily inoculated is to be kept in mind in considering these results. As in the seedlings examined in the nursery beds, when a root system was partly rotted it was only the younger portions of the roots that were affected. The evidence obtained from this experiment needs to be amplified by experiments with other coniferous hosts, other strains of the fungi, and under other conditions. The experiment just described furnishes the only evidence available on the relation of the important fungi *Pythium debaryanum* and *Corticium vagum* to the root-rot of conifers and is therefore presented as a preliminary contribution.

TABLE X.—*Results of root inoculations of older pine seedlings with damping-off fungi.*

Host and inoculating fungus.	Number of—		Seedlings which developed root-rot (per cent).				
			Tops still healthy.				
	Pots.	Seedlings.	Root recovery.		Average of individual pots.	Killed.	Total.
			Started.	Not started.			
1	2	3	4	5	6	7	8
Pinus ponderosa:							
Pythium debaryanum, strains 295, 550, and 810.[a]	9	71	27	25	53±4.5	4	56
Corticium vagum, strains 147, 213, and 747.[a]	9	56	16	34	51±3.5	4	54
Fusarium moniliforme, strains 249, 251, and 260.[b]	9	64	19	27	42±6.2	0	45
Fusarium ventricosum	3	18	17	39	50	0	56
Controls	6	41	2	15	22±6.5	0	17
Controls without rice	3	18	0	17	23	0	17
Pinus resinosa:							
Pythium debaryanum	9	140	3	16	18±4.0	12	31
Corticium vagum	9	146	3	16	21±2.4	13	33
Fusarium moniliforme	8	128	0	11	12±3.7	2	13
Fusarium ventricosum	3	39	0	5	4	0	5
Controls	6	115	0	3	4±2.0	6	10
Controls without rice	3	51	0	0	0	2	2

[a] For relative virulence of these strains on younger seedlings as compared with other strains of the same species, note their position in figures 11 and 14.
[b] For performance of these strains in inoculations at time of sowing, see an earlier publication (68, table 2).

The figures in column 7 give information as to the percentage of late damping-off resulting from the inoculations. A certain percentage of the early type of damping-off appeared in some of the

pots, as there were still present a number of soft-stemmed seedlings from seeds which were slow in germinating. These younger seedlings were excluded in counting the dead, the rule being to include only plants which had developed a sufficiently rigid stem to remain upright after death. Comparison of the percentage of killed with the total percentage attacked for the two pines is rather interesting. As has already been pointed out, while *Pinus resinosa* suffers very heavy damping-off losses at a number of nurseries it seems to be less susceptible than some other species to parasitic injury during the sprouting period, before the seedlings appear above the soil surface. Observation of beds of this species during different seasons has indicated that it has not a greater susceptibility, but rather the fact that its susceptibility lasts longer, which causes it to suffer as seriously as it does at certain nurseries. It is indicated in Table X that the succulent root tips of *Pinus ponderosa* are just as easily attacked by damping-off parasites as those of *P. resinosa*—in fact, considerably more easily attacked, as indicated by the figures in column 8. With the *P. ponderosa* seedlings, however, the older parts of the roots had become resistant at this age in nearly all cases, while of the affected *P. resinosa* seedlings more than one-third were still unable to limit the lesions, and death resulted.

In general, this experiment indicates that *Corticium vagum* and *Pythium debaryanum* are able to cause the death of some pine seedlings which have developed rigid stems and that both are also able, as has been found by other workers in the case of sugar beets, to cause "root sickness," the rot of the younger portions of the root systems, in seedlings which have developed too much resistance to be killed. The evidence for the parasitism of the two Fusarium species on these older root systems is not so good; as in the experiments on younger seedlings, their ability to attack the pines is probably less than that of the other two fungi. Further inoculation experiments are desirable both with these fungi and with others on the roots of seedlings too old to succumb to the more ordinary types of damping-off.

RELATION OF ENVIRONMENTAL FACTORS TO DAMPING-OFF.

In the earlier section dealing with disease control, mention was made of the general belief on the part of men who have had experience with seedling diseases that damping-off is favored by thick seeding, by much organic matter, especially by poorly rotted manure in the soil, and by excessive moisture in the air and soil. It is also commonly stated that high temperature favors the disease; on this point there is perhaps a less general agreement. Practically all the evidence on these points is observational.

DENSITY OF SOWING.

The relation between the disease and thick sowing was strikingly indicated for tobacco seedlings in a single experiment by Johnson (82). For pines the only available information is from four experiments on *Pinus banksiana.* The results of the first two appear in figure 19. In both experiments there is an indication of an increase in the percentage of diseased plants as the seed density is increased. There is, however, no such marked relation as in Johnson's work. As the pines were sown in drills, they were so close together even in the less dense plats that no very great increase in the ease of spread of the disease was to be expected from increasing the density. Greater differences should be expected in broadcast beds. That heavier losses have been found in drill-sown beds than in those sown broadcast (69, 139) is presumably explained by the fact that with equal numbers of seed per square foot of seed bed the seedlings are much closer together in drills than in broadcast beds, and thus the spread of the mycelium of parasites from one seedling to another is facilitated.

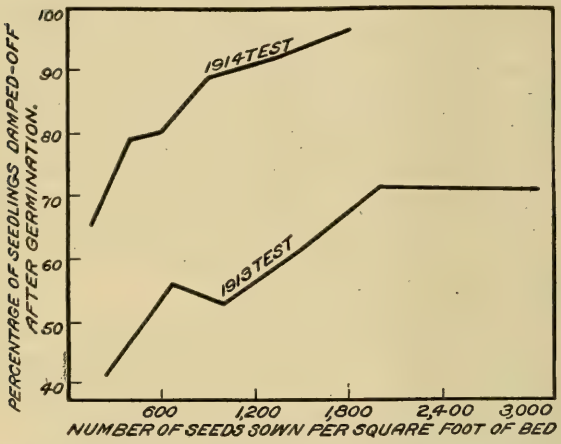


FIG. 19.—Diagram showing the extent of damping-off in drill-sown *Pinus banksiana* in plats with different seed densities. The regular seed density at this nursery was 600 seeds per square foot.

Two tests of different seed densities were also made in 3-inch pots of autoclaved soil in the greenhouse. Each regular pot was sown with 28 seeds (equivalent to 600 per square foot). The pots were inoculated by adding to each a single small fragment of an agar culture of *Pythium debaryanum.* Uninoculated pots showed an emergence of approximately 50 per cent of the seed and were entirely free from subsequent damping-off in both experiments. The results appear in Table XI.

In this case not only the damping-off after emergence but the loss before the seedlings appeared bore an apparent relation to sowing density. In the field experiments there was no evidence that the loss before the seedlings appeared was affected by seed density.

TABLE XI.—*Results of inoculation, at the time of sowing, with Pythium debaryanum on Pinus banksiana in different sowing densities in pots of autoclaved soil.*

[The percentages of "Damping-off," columns 4 and 7, are based on the number of seedlings; the percentages given in columns 3, 5, 6, and 8 are based on the number of seeds.]

Density of seed sowing.	Number of pots in experiment.	Results (per cent).					
		Experiment 58.			Experiment 59.		
		Emerged.	Damping-off.	Survival.	Emerged.	Damping-off.	Survival.
1	2	3	4	5	6	7	8
Regular	10	15	43	10	26	13	23
Double	5	8	65	3	8	91	1
Triple	5	1	100	0	11	34	7
Regular, but 10 additional seeds near point of inoculation	5	6	33	4	17	37	11

MOISTURE AND TEMPERATURE FACTORS.

The relation of damping-off to moisture and temperature are subjects less easily studied. In 1907 and 1908 Mr. W. H. Mast, then supervisor of the Nebraska National Forest, conducted daily counts of the number of seedlings damped-off and compared these records with temperature and rainfall records. The writer in 1909 repeated his work, maintaining parallel records of damping-off, air and soil temperatures, soil moisture, atmospheric humidity, wind movements, and evaporation. The 1909 records of damping-off, temperature, soil moisture, and evaporation appear in figure 20. The damped-off seedlings were counted and removed in the morning and evening, the day period thus being in most cases 10 to 11 hours and the night period 13 to 14 hours. Because the period was not always the same length, the data are reduced to a per hour basis. Air temperature was recorded by a sheltered thermograph 3 feet above the soil surface. The evaporation graph represents the mean loss per hour from two porous cup atometers of the writer's own design, in which the rather long and slender Chamberlain filter bougie was used and supported in a horizontal position just above the soil surface so as to be under as nearly as possible the same atmospheric conditions as the seedlings. The two bougies were placed at right angles to each other in order to eliminate as far as possible the effect of change of wind direction on their mean loss. While the rain-correction mounting had not at that time come into use, the error due to rain absorption appeared negligible; atometers filled shortly before rainfall were read immediately after without any gain being found in the water in the reservoir. The psychrograph and wind-movement records are not presented, as the evaporation values are more easily interpreted. Soil moisture was periodically determined in the soil of the

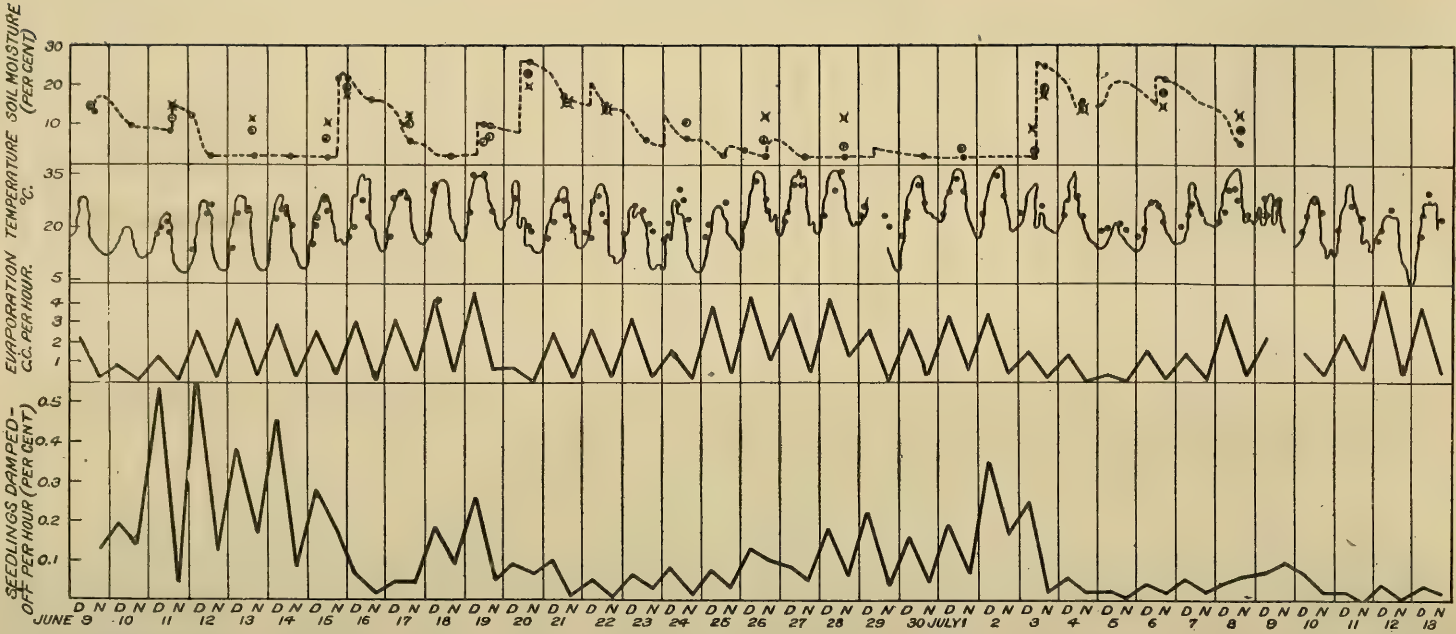


FIG. 20.—Diagram showing the progress of damping-off in beds of *Pinus banksiana* at a nursery in Nebraska and indicating the moisture and temperature conditions. The evaporation from porous-cup atmometers was measured and the dead seedlings counted, night and morning. As the day (D) and night (N) periods into which the time was thus divided were not of equal length, these figures are converted into an hourly basis. The temperature curve is taken from a sheltered thermograph 1 meter above the surface of the beds, while the dots accompanying this curve indicate readings of a thermometer whose bulb was buried 3 cm. below the soil surface. For the temperature and soil-moisture records, the vertical lines indicate 6.00 a. m. Explanation of symbols referring to soil moisture: ●=At depth of 0 to 0.6 cm., ⊙=at depth of 0 to 2.5 cm., ×=at depth of 2.5 to 5 cm.

plats on which the seedling counts were conducted, each determination representing two, and in some cases four, points. The determinations for the upper one-fourth inch of soil, made more frequently than for lower levels, are connected in figure 20 by a dotted line, which gives some idea of the amount of moisture in the surface soil during the periods between determinations. The determinations were too infrequent to permit anything more than an estimate of the moisture conditions between determinations, but the writer, having before him the records of the times and amounts of rainfall and artificial watering as well as the evaporation and soil-moisture determinations, is in a better position to make such an estimate than the reader. The dotted line which gives this estimate should not be depended on to show what the percentage of moisture was at any one time, but is believed reasonably reliable as showing whether in general the soil was wet or dry. In interpreting the soil-moisture records, it should be kept in mind that the soil was very sandy, the wilting coefficient of composite samples from various parts of the nursery, as determined by the indirect method of Briggs and Shantz in the Laboratory of Biophysical Investigations of the Bureau of Plant Industry, being only 3.4 per cent. The hygroscopic moisture in dry air for the soil of the plats actually under consideration was indicated by repeated determinations for the surface soil on dry days to be in the neighborhood of or slightly below 2 per cent. The nursery is located in a region of large temperature fluctuations, where the air during the day is generally dry, and consequently the dew is heavy at night.

The first result of interest is the difference between the damping-off for the day and the night periods. In the records of every day but two, more seedlings went down during the day period than during the night, the differences in most cases being large. As the evaporation and temperature showed similar day and night fluctuations, it is difficult to say whether temperature or moisture conditions were responsible. The other interesting result brought out by the graphs is the sudden drop in the general level of the damping-off graph following the rains of June 15, June 19–20, and July 3. In each of these three cases the damping-off came up again only after the soil moisture came down.

The fact that in the daily fluctuations the damping-off varied directly with the evaporation rather than inversely is an apparent contradiction of the generally accepted doctrine that moisture favors the disease. This contradiction is, however, only apparent. During the first part of the damping-off period, when the seedlings are still soft, the recognition of damping-off depends on the decay of that part of the stem just above the soil surface which allows the seedling to fall over. This usually takes place at this nursery as

a result of the extension upward of lesions which have started on the parts a little below the soil surface. It is supposed that such decay takes place most rapidly at high temperatures and that it is the temperature rather than the evaporation graph which the damping-off is following in these early day and night fluctuations. During the latter part of the damping-off period a dying seedling shows its first signs of distress in the drying up of its leaves, the stem being too stiff to go down until after the infection has gone far enough in the roots to cut off most of the water supply. It is, of course, under dry conditions that such a sign of distress will be most in evidence. During the latter part of the damping-off period it is therefore altogether likely that the day and night fluctuations are caused, at least in part, by the higher evaporation rate which obtains during the day. This is a relation not to the rate of progress of the disease, but rather *to the rate at which the symptoms of disease appear in plants already seriously affected.*

The drop in damping-off following the increased soil moisture of June 15, 19–20, and July 3 also apparently contradicts established doctrine. While it is ordinarily true that a wet soil is a cold soil and that in the rainy weather which causes wet soil the evaporation is usually low, it does not seem possible on inspection of the graphs for these items to attribute entirely the reduction of damping-off during these periods of wet soil either to low temperature or to low evaporating power of the air. Lowered soil temperature probably had something to do with the reduced loss following the rains. It is also suggested that a sudden change in moisture content may temporarily hinder a soil fungus by decreasing its air supply. In this sandy soil the fungi can work at very considerable depths during dry periods. Initial lesions have been found as much as 12 inches below the surface. If this soil is as completely changed in its aeration qualities by wetting as the sandy soil with which Buckingham (19) worked, a rain might result in a rather sudden change in the level at which the fungus is able to operate.

On the whole, the graphs tend to confirm the common statement that high temperature favors damping-off. It must, however, be borne in mind that in uncontrolled field plats several factors vary simultaneously, and it is impossible to definitely attribute any observed phenomenon to any one of them. Furthermore, it is not possible to say for the seedlings at different ages just how long it will take a factor to exert an effect on the damping-off curve. An additional consideration is that a method of investigation which gives entirely reliable information on the speed with which the disease develops does not necessarily throw light on the conditions under which the greatest total amount of disease can be expected before the seedlings become old enough to resist attack. High temperatures,

within reasonable limits, are expected to increase the speed with which the disease works, but these should also hasten the development of the host to a point at which infections are unable to cause death. It is the total amount of damage in the beds rather than the damage per unit of time which is of practical importance. For a number of reasons, then, the method followed in obtaining the data for these graphs can not give information of maximum value. While data of the sort mentioned are of undoubted interest and would be of still more value if the records had been commenced when the first seedlings appeared instead of a few days later, the relation of any specific factor to the total extent of the disease can be better determined by comparing plats in series in which the factors are as far as possible controlled and varied one at a time. To vary soil moisture and soil temperature independently will prove somewhat difficult, but it can be done with the proper facilities. Some work with environmental factors should be done under conditions of artificial inoculation in the greenhouse, in which the different damping-off parasites can be experimented with separately, as it is obvious that the factors which favor the activity of one may not be favorable for another.

CHEMICAL FACTORS.

Chemical factors are presumably also important, as the soil is in most cases the culture medium for both the parasite and the host. The much greater activity of *Pythium debaryanum* in autoclaved soil than in untreated soil may be due to the larger quantity of soluble organic matter commonly present in autoclaved soil. *Pythium debaryanum* has been found more sensitive to unfavorable substrata in artificial culture than *Corticium vagum* and is apparently more dependent on soil organic matter in the nurseries than is *C. vagum*. For example, in the normal humus-containing surface sand in the beds at Cass Lake, Minn., both Pythium and Corticium occurred frequently in the damped-off seedlings, while in beds a few feet distant, from which enough of the surface soil had been removed to leave no humus, nearly all the damping-off foci contained abundant Corticium, and no Pythium could be found. With both fungi and, in addition, with two species of Fusarium (68) heavy inoculation has been more successful in experiments at the time of sowing than light inoculation. This has been thought possibly due in part to the larger amount of nutrient substratum added in the heavy inoculations, allowing better saprophytic development of the fungus in the soil. In each of the two experiments with Pythium reported in Table XI, a 5-pot unit was treated with corn-meal infusion and another with prune infusion at the time of inoculation. In both experiments germination was lower, damping-off after germination higher, and the survival less than half as great in the pots with

infusion as in the inoculated pots not so treated. In the first experiment 5-pot units of unheated soil were also inoculated in the same way. In these also both the units which received infusions showed less germination and more loss after germination than the unit which received no infusion, though the differences were smaller than in the autoclaved soil. In the second experiment the light inoculation used failed to cause material loss in the unheated soil units, even though two of them were treated with the infusion as in the previous test and two others received triple portions of the infusion.

The experience in the nurseries, in which heavy applications of manure, and especially poorly rotted manure, in a number of cases have apparently resulted in increased disease, and the finding of Fred (43) that green manures recently plowed under favored the work of Corticium have already been mentioned. The addition of dried blood at two nurseries in Kansas was in both cases followed by very much heavier loss than in the controlled plats. The only instances known to the writer in which the addition of organic matter to the soil has shown any indication of materially decreasing damping-off (with the exception, of course, of the organic disinfectants) are the result reported by Gifford (46) with tankage, a single case in the writer's experience with bone meal, and the cases in which cane sugar has seemed to decrease losses somewhat (67). It is of some interest to note that the experience available also indicates increased disease as a result of the addition of inorganic nitrogenous substances. Sodium nitrate and sodium nitrite have both given some indication of increasing damping-off. Ammonium sulphate in six separate series has in every case resulted in decreased stands, though unfortunately in experiments in which the damped-off seedlings were not counted. Ammonium hydroxid, though apparently having some initial value as a disinfectant, as indicated by early damping-off losses, in a number of cases has been followed by very heavy total losses. This experience is of some interest in view of the apparently rather general belief that plants on a soil rich in nitrogen are especially susceptible to disease.

The chemical factor for which there is perhaps the most evidence of a relation to damping-off of conifers is acidity. The fact that sulphuric-acid soil treatment has been found to be one of the most effective means of controlling the disease, that its value is mainly lost if lime is later added to the soil, that soil treatment with sulphur in a number of cases has seemed to decrease the disease, and that lime alone and wood ashes have had either no effect or have apparently increased the damping-off whenever they have been tried, all suggest that soil acidity is not favorable to the disease. Additional indication of this appears in figure 12. The acidity determinations serving as the basis for the graph were made by Dr. L. J. Gillespie,

of the Bureau of Plant Industry. The estimates of the relative seriousness of damping-off are very approximate, based in part on observation only. The stations at which damping-off is rated as 1 are places at which it has been reported by nurserymen or foresters as negligible or absent. The estimates for stations 10, 11, 14, and 15 are based entirely on the reports of others, and for station 5 on the basis of counts of damped-off seedlings made by Mr. R. G. Pierce and Mr. Glenn G. Hahn. The writer personally has made the estimates or checked the estimates of the nurserymen at the other stations. A considerable degree of correlation between the hydrogen-ion exponent and the amount of damping-off appears on the face of the graphs, the coefficient being 0.75 ± 0.07. If the correlation is calculated with the H^+ concentration itself instead of its negative exponent, the coefficient, in this case itself negative, is not so high (-0.58 ± 0.11). All of the above data on acidity relation have been picked up incidentally in connection with other work and are merely suggestive. The suggestion, however, seems sufficiently strong to warrant further experimental work directed specifically at the relation between soil acidity and the disease.

The indication in the graph that damping-off is not serious in soils in which the hydrogen-ion exponent (P_H)[6] is less than 6 is of particular interest, in view of the experience of Hawkins and Harvey (71) with cultures of *Pythium debaryanum* on potato juice. They obtained good growth through a range of acidity from P_H 3.4 to 5.8, with no growth or practically none at 3.06 or 8.4. If this represents the acid tolerance of the fungus in the soil solution, it is evident that ordinarily acid soils can not be expected to remain free from damping-off because of inhibition of this particular fungus. This suggests that the apparently salutary influence of soil acidity in decreasing the damping-off of some of the conifers may be exerted in the direction of increasing the resistance of the host rather than of inhibiting the parasites. In any case, it must be kept in mind that as the numerous conifer hosts commonly grown in nurseries have many different habitat preferences and many very different parasites of potential importance, it is not to be expected that there will be found any such constant relation between any factor and the amount of disease as would be expected in a disease in which only a single parasite and a single host are involved.

[6] P_H 6 is equivalent to a hydrogen-ion concentration, expressed in mols per liter, of 1×10^{-6} or 0.000001. The higher the exponent, the smaller the hydrogen-ion concentration. An exponent of 7 means approximate neutrality. In dealing with this exponential form of expression, it should be kept in mind that P_H6 means ten times and P_H5 one hundred times the hydrogen-iron concentration indicated by P_H7. Conversely, the concentration of hydroxyl-ions at P_H7 is one hundred times as great as at P_H5.

BIOLOGIC FACTORS.

Mention has already been made of two strictly biologic factors which may influence the amount of damping-off. Taylor (138) and Rathbun (106) have found Fusarium not only at considerable depths in the soil of pine seed beds, but viable Fusarium spores without hyphæ in the alimentary canals of earthworms and insect larvæ in the soil, and they attribute to the migrations of these and to the tunnels which various animal forms make in the soil a possible importance in the distribution of damping-off Fusaria. A likely relation between *Corticium vagum* epidemics in pine seed beds and the character of the weed flora has also been considered (66).

The relation between the damping-off parasites and other microorganisms in the soil is also a matter of some interest. The effect of the microfauna of the soil on the microflora in general has been considered by Russell and others in a number of papers. The effect of soil disinfection by heat in favoring the work of artificially introduced soil-inhabiting fungous parasites, apparently a rather frequent phenomenon and quite evident in the inoculation experiments with *Pythium debaryanum* reported in the present bulletin, has been in other cases attributed to the removal of bacteria and other fungi which might compete with the parasites (36, 80). Heating soil is known to produce physical changes and also very considerable chemical changes both in organic and inorganic substances. These must not be ignored in considering the effect of previous soil heating on parasite activity. With a view to determining whether all the difference noted in the behavior of *P. debaryanum* in heated soil is due to the direct effects of the heating or in part to the elimination of competing microorganisms, an experiment was conducted in 3-inch pots of autoclaved soil in which 111 of them were inoculated with agar cultures of the Pythium at one point in each pot shortly after seed sowing. The seeds sown in each pot approximated 136, considerably more than are used on equal areas of nursery seed bed. Of these, fifteen 5-pot units and one 3-pot unit had been inoculated broadcast with rice or nutrient agar cultures of various organisms supposed to be saprophytic on pines. These included *Phoma betae*, *Phoma* sp., *Chaetomium* sp. (from a maple root), *Rhizopus nigricans*, *Trichothecium roseum*, *Trichoderma koningi*, *Aspergillus* spp. (including one with black and one with bright-colored spore heads), *Rosellinia* sp. (from soil), *Penicillium* sp., an undetermined bacterium, and three undetermined higher fungi. The whole 78 pots inoculated with *P. debaryanum* and saprophytes, the percentages being based on the total number of seeds in the case of emergence and survival and on the number of seedlings which appeared above ground for damping-off loss, as compared with those which had received the parasite only, gave results as follows:

Pots with saprophytes: Emergence, 47.4±0.86 per cent; damping-off, 9.1 per cent; survival, 41.0±1.23 per cent.

Pots without saprophytes: Emergence, 35.7 per cent; damping-off, 14.3 per cent; survival, 29.2 per cent.

It has been noted in the attempts to diagnose damping-off by planted-plate cultures that when Rhizopus appears *Pythium debaryanum* is not frequently obtained. It is therefore of some interest to note that in this case, in the two 5-pot units which received Rhizopus in addition, the parasite killed only 1.2 per cent and 3.3 per cent, respectively, of the seedlings which appeared above the soil.

At the same time pots not inoculated with parasites were sown, 16 other 5-pot units were inoculated with the same saprophytes as those used in the Pythium inoculated pots, while 25 pots were left entirely without inoculation. A certain amount of damping-off occurred in these pots also as a result of accidental infection. The results were as follows:

Pots with saprophytes: Emergence, 47.8±0.8 per cent; damping-off, 3.9 per cent; survival, 43.7±0.95 per cent.

Pots without saprophytes: Emergence, 43.0 per cent; damping-off, 5.2 per cent; survival, 38.4 per cent.

It is of some interest to note that in these pots also the 5-pot units inoculated with Rhizopus suffered less from damping-off than the average of the saprophyte-inoculated pots.

The probable-error values given above are based on the variability of the emergence and survival figures of the different 5-pot units. No individual figures are available to serve as a basis for the determination of the variability of the pots without saprophytes. The 16 units which support the error determinations are, of course, not a sufficient number to give an entirely reliable index of variability, though these 16 units are respectively derived from the combination of a total of 78 and 80 ultimate units. The distribution of the data appears to be such as to justify the use of probability methods. Of the 64 items which went into the germination and survival calculations, 34 showed a deviation equal to E_s (probable error of a single unit), 9 to a deviation equal to $2E_s$, and only one a deviation equal to $3E_s$.

All of the above figures are based on the results at the end of 10 days after average emergence in the pots. The pots were kept on the benches till practically all damping-off had ceased, 36 days after emergence. As additional accidental infection with saprophytes certainly, and probably with parasites, occurred during this period, the results at the end of the tenth day are considered to give a better indication of the effect of the original inoculations. It is of some interest, however, to note that during the period from the tenth to the thirty-sixth day the difference between the pots to which sapro-

phytes had been added and those which received no saprophytes showed a slight increase, proportionally as well as in the absolute figures. At the end of the 36 days the survivals on all the pots were counted separately. The average number of seedlings per pot were as follows:

Without Pythium:
Without saprophytes, 42.8±2.3; with saprophytes, 52.1±1.1
With Pythium:
Without saprophytes, 30.1±2.4; with saprophytes, 48.1±1.4.

The difference in the survivals in favor of the pots with saprophytes in the first case is 9.3±2.5, three and two-thirds times its probable error. In the second case it is 18.0±2.8, more than six times its probable error.

In general, it appears that in this experiment the inoculation of sterilized soil with saprophytes gave the seedlings some protection both against damping-off due to accidental infection with unidentified parasites and from the additional loss caused by light inoculation with *Pythium debaryanum*. The indication is, as would be expected, that only part of the favoring influence of heat sterilization of soil on introduced *P. debaryanum* is immediately due to the elimination of competition with other fungi. If a mixture of different bacteria and fungi had been added to each of the pots instead of but one or two organisms to each 5-pot unit, the effect might have been more marked.

It will be noted that for all the groups (fig. 18), whether with or without Pythium inoculation and with or without added parasites, the frequency polygon is asymmetrical, indicating by its shape, as did the frequency polygon of survivals in pots inoculated with Rheosporangium (fig. 17), that with infections which do not kill all of the seedlings the selection tends to be by pots rather than by seedlings. In other words, in pots in which the parasites succeed in killing any of the seedlings, they usually kill a considerable number. The tendency is illustrated not only by inspection of the graphs, but by the variability of the different groups. The greater variability in survivals between different pots was in both cases in the groups in which both the damping-off after emergence and the survival percentages indicated the largest loss. The percentages of seedlings damped-off during the entire 36 days following emergence and the coefficients of variability of the survivals of the individual pots at the end of that time are as follows:

Without Pythium:
Without saprophytes, 15.5 per cent damped-off; coefficient of variability, 39±4.2 per cent.
With saprophytes, 11.1 per cent damped-off; coefficient of variability, 28±1.6 per cent.

With Pythium:

Without saprophytes, 27.5 per cent damped-off; coefficient of variability, 67±7.8 per cent.

With saprophytes, 16.9 per cent damped-off; coefficient of variability, 39±2.4 per cent.

This tendency has been frequently observed in experiments in which inoculum is applied to the soil at the time of sowing. Even in experiments in which a relatively small proportion of the seedlings are killed, some of the pots are nearly or entirely cleaned out. It is taken as an indication that failure of inoculation to give results is often due to the inability of the fungus to maintain itself in a vigorous condition till the germinating seed is far enough along to allow easy infection. It may also be in part due to lack of uniformity of the soil in different pots affecting virulence of parasites or resistance of hosts.

In addition to this experiment on autoclaved soil, a somewhat similar experiment was conducted in a nursery in the Kansas sand hills on soil which had been treated with sulphuric acid, followed by lime raked into the soil. Saprophytes, for the most part the same strains that had been used in the experiment in the greenhouse, were added to 24 plats, each of one-half square foot, of *Pinus banksiana* and 24 of *P. ponderosa*, with 16 interspersed plats of each species serving as controls. The saprophytes were growing on rice, part of which was added to the plat with the inoculum in addition to the fungous mycelium. Damping-off was rather heavy in this soil from accidental infection or from parasites which survived the initial acid treatment, no parasites having been artificially introduced. The loss was probably due to *Corticium vagum* or *Fusarium* spp. rather than to *Pythium debaryanum* in this case. In both pines, emergence was slightly better in the control plats than in those to which the saprophytes had been added, the difference for *Pinus banksiana* being less than half its probable error and for *P. ponderosa* slightly more than its probable error. Damping-off for the first few days after emergence was somewhat less in the controls in one species, but higher in the saprophyte-inoculated pots in the other. The saprophytes therefore gave no evidence of effective competition with the parasites on this acid-lime treated sand.

While the competition for water which seems to be the form of competition most common among green vascular plants is not likely to be of significance between fungi such as those which cause damping-off, a very little observation of the growth of mixed cultures of the parasites and other organisms in Petri dishes is sufficient to make one realize that the latter may very considerably decrease the activity of certain of the parasites. In nutrient agar most of the fungi and bacteria introduced from the soil in attempting parasite isolations,

as well as to a less extent the paramecia, nematodes, and amœbæ which develop in such plates, exert a very considerable limiting influence on the growth of most of the damping-off fungi. That they should also limit the growth of parasites in soil, whether by the production of toxic compounds, the exhaustion of food materials, or in other ways, seems entirely reasonable. The results in the writer's experiments on heated soil warrant the suggestion that further trials should be made of the introduction of vigorously growing bacteria or molds, preferably mixed cultures containing a number of different organisms, on seed beds which have been disinfected by some such method as steam or hot water, which leaves the soil in a favorable condition for the development of accidentally reintroduced parasites. If such treatment should be successful in improving the rather disappointing results with soil heating at some nurseries, it might easily become of practical value, as the cultivation of certain of the more easily grown saprophytes on a scale large enough to yield considerable quantities of bacterial or spore suspensions should be fairly easy and entirely practicable in an operation as intensive as that of raising coniferous seedlings.

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SUMMARY.

(1) Damping-off in nurseries is caused mainly by seedling parasites which are not specialized as to host; *Pythium debaryanum* and *Corticium vagum* are probably the most important of these. Damping-off of various herbaceous hosts, including ferns, is often caused by specialized parasites which are limited to a particular host or group of hosts. *Phoma betae* is a rather extreme example of such specialization. For the conifers all the damping-off appears to be due to parasites of the generalized type.

(2) Damping-off of trees, as of herbaceous plants (with the exception of the cases caused by specialized seed-carried parasites), is ordinarily serious only in seed beds or cutting beds in which large numbers of plants are crowded together in a small space. In most of the forest nurseries it is a much more serious matter in conifers than in dicotyledonous seedlings.

(3) The most serious losses in conifers are ordinarily from the root-rot type of damping-off, occurring soon after the seedlings appear above ground and while the hypocotyls are still soft. Losses due to the killing of dormant or sprouting seed by parasites before the seedlings appear above the soil are also frequently serious, sometimes necessarily more so than the later types, as in extreme cases more than half of the seed or young seedlings are destroyed in this way. Damping-off due to infections of parts above the soil surface is serious only under extremely moist atmospheric conditions. The late type of damping-off, in which the roots are rotted after the stem becomes too rigid to be easily decayed, is ordinarily less important than the early types. Seedlings more than 2 months old are ordinarily able to recover from infections by the damping-off fungi. Even after the first month, seedlings with part of their root system killed often recover.

(4) It is possible that damping-off has a certain value as a selective agent by eliminating weak individuals in the seed-bed stage and allowing only the best trees to go into forest plantations. This value, however, is believed to be slight. Disinfectant treatments of seed beds, even when controlling early parasitic losses very well, allow a considerable percentage of disease during the last part of the damping-off period, often as much as occurs at the same stage of development in untreated beds. As it is only this late damping-off in which differences in individual resistance of the seedlings seem to be of importance in determining whether or not they succumb, it is believed that whatever selective value the disease may have will appear in a larger proportion of the damping-off in the treated than in the untreated beds.

(5) Of the different conifers, reports are available as to the susceptibility of 63 species. Species which are especially susceptible at some nurseries may prove more resistant than the average at others. *Pinus resinosa*, which is especially subject to loss at some nurseries, is believed to be so because its growth at these nurseries is slow and its period of susceptibility is therefore especially long. In its early stages it does not seem especially susceptible. Representatives of all the commonly grown genera of the Abietoideæ have been reported by one observer or another as decidedly susceptible. The reports on junipers and other members of the Cupressoideæ, on the other hand, have indicated a considerable amount of group resistance to damping-off.

(6) The best control method appears to be the disinfectant treatment of the seed-bed soil before or immediately after seed is sown. Sulphuric acid has been found very useful for conifers, as they are apparently especially tolerant of acid treatment. No method has yet been worked out to a point at which all of its details are entirely

satisfactory, though the acid treatment has now been in successful use for several years at some nurseries. At most nurseries, if the minimum effective quantity of acid is used, there is no need of any special precautions to prevent injury to the seedlings. It is not expected that any single treatment can be found that can be universally applied without change in details irrespective of differences in soil characters and in fungous flora.

(7) *Corticium vagum* and *Fusarium* spp. have been previously shown to be parasitic on pine seedlings. Different strains of *C. vagum* are found to vary considerably in their ability to cause damping-off, certain strains being consistently destructive and others much less active in tests conducted on different species of pine and several years apart. The differences in activity between strains were greater, and apparently rather more constant from one experiment to the next, than with Peltier's strains in his carnation experiments. Comparison of the results on pine with those of Edson and Shapovalov on potato gives some indication that strains vigorously parasitic on one of these hosts are likely to be parasitic on the other also.

(8) *Pythium debaryanum*, reported on many hosts and proved to be parasitic on few, is shown by repeated inoculation, reisolation, and reinoculation to be capable of causing the damping-off of seedlings of pine species. The identity of the fungus causing the damping-off of conifers with that attacking dicotyledons has been established by cross-inoculations as well as by morphological comparison. Inoculations on unheated soil are much less destructive than on heated soil. *Pythium debaryanum* has been obtained in culture from *Picea engelmanni*, *P. sitchensis*, *Tsuga mertensiana*, *Pinus banksiana*, *P. nigra austriaca*, *P. ponderosa*, *P. resinosa*, and *Pseudotsuga taxifolia*. In addition, fenugreek (*Trigonella foenum-graecum*), cowpea (*Vigna* sp.), and rice (*Oryza sativa*) are reported as apparently new hosts among the dicotyledons. In inoculations the fungus has been successfully used on *Pinus banksiana*, *P. ponderosa*, *P. resinosa*, and in a preliminary experiment on *Pseudotsuga taxifolia*. It had already been successfully used in preliminary inoculations on *Picea canadensis* by Hofmann (77).

Differences in parasitic activity on pine are found between different strains of *Pythium debaryanum*. These differences are not as large and partly for this reason their constancy is not quite as conclusively demonstrated as in the case of the strains of *Corticium vagum*.

(9) *Rheosporangium aphanidermatus* Edson, a parasite of radish and sugar beet, in many ways closely resembling *Pythium debaryanum*, has killed seedlings of *Pinus banksiana* and *P. resinosa* in certain experiments, and reisolations and reinoculations have been

made. The strain available is much less destructive to the pines than most of the *P. debaryanum* strains used, and as the fungus has never been isolated from coniferous seed beds it is not believed to be of any great importance in forest nurseries.

(10) *Phytophthora* sp. from *Pinus resinosa* seedlings has been successfully used in inoculation on *Pinus resinosa* and in a preliminary test on *P. ponderosa*. The strains available have been less destructive to the pines than *Pythium debaryanum* and the stronger strains of *Corticium vagum*. It is not common. Its relation to *Phytophthora fagi*, the European damping-off parasite of both conifers and dicotyledons, which has not been reported in this country, is being investigated.

(11) A fungus referred to *Pythium artotrogus*, also obtained from damped-off *Pinus resinosa*, has indicated a very low degree of parasitism on this host, even less than that shown by the Rheosporangium and Phytophthora strains. An addition is made to the statements in a previous paper concerning the ability of *Botrytis cinerea* to cause damping-off in conifers.

(12) The results of the cultural or direct examination of 742 disease foci in seed beds of various conifers are reported. *Pythium debaryanum* in the plate-culture examination method, considered more reliable than direct examination, appeared in 51 per cent of the foci from untreated beds, while *Corticium vagum* was found in 19 per cent. In foci in beds treated with various disinfectants, *P. debaryanum* was identified in 38 per cent of the foci and *C. vagum* in only 4 per cent. When direct microscopic examination was substituted for isolation, *C. vagum* was found on a larger proportion of the seedlings. It was not found at all in soil which had been heated. The relative ease with which it appears to be controlled by soil disinfection is in agreement with its poor adaptation for aerial distribution. It was found more commonly in cases in which the seedlings were directly examined than when cultures were made. In view of the fact that at least some of the Corticium foci extend rapidly and include very large numbers of seedlings, it seems that the Corticium may be as important as *P. debaryanum* in causing the damping-off of pines.

(13) *Fusarium* spp. have occurred more commonly in plate cultures than either of the above-mentioned fungi. Because little is known as to the parasitism of different species of this group on conifers, it is not possible to make any statement regarding the importance of the individual species. The evidence as a whole indicates so much importance for *Pythium debaryanum*, *Corticium vagum*, and for the *Fusarium* spp. considered as a group that no one of the three can be safely said to be more important than the others. None of the other fungi considered appear to be of real economic rank in the United States.

(14) In an inoculation experiment on the roots of pines 1½ months old, *Corticium vagum* and *Pythium debaryanum* were found able to cause the death of seedlings which had already developed rigid stems and to destroy the younger parts of the roots of seedlings which they were unable to kill. Indications were also obtained of similar but less vigorous action by *Fusarium moniliforme* and *F. ventricosum*.

(15) Data are given confirming the general belief that thick sowing favors the disease and indicating that soil acidity is, in general, unfavorable. Preliminary data on the relation of temperature and moisture to the disease are also presented. The parasitic activity of *Pythium debaryanum* in steamed soil was in one extensive test considerably decreased, following the inoculation of the soil with various saprophytes; this indicates both that competition of different fungi is a factor to be considered and that the inoculation of treated soil with saprophytes may sometimes prove of value in increasing the efficiency of heat disinfection. It is pointed out that with such a complex of parasites capable of producing identical symptoms on a number of different hosts, no relationship between environmental factors and the disease can be expected to hold in all cases.

LITERATURE CITED.

ATKINSON, GEORGE F.

(1) 1892. Some diseases of cotton. Ala. Agr. Exp. Sta. Bul. 41, 65 p., 25 fig., 1 pl.

(2) 1895. Damping-off. N. Y. (Cornell) Agr. Exp. Sta. Bul. 94, p. 233–272, fig. 55, 6 pl.

(3) 1902. Studies of some tree-destroying fungi. *In* Trans. Mass. Hort. Soc., 1901, pt. 1, p. 109–130.

(4) BARRE, H. W.
1912. Cotton anthracnose. S. C. Agr. Exp. Sta. Bul. 164, 22 p., 7 pl.

(5) BARY, A. DE.
1881. Zur Kenntniss der Peronosporeen. *In* Bot. Ztg., Jahrg. 39, No. 33, p. 521–530; No. 34, p. 537–544; No. 35, p. 553–563; No. 36, p. 569–578; No. 37, p. 585–595; No. 38, p. 601–609; No. 39, p. 617–625, pl. 5.

(6) BATES, CARLOS G.
1907. Timber fungi, with special reference to the pines. *In* 38th Ann. Rpt. Nebr. Hort. Soc., 1907, p. 201–208.

(7) ——— and PIERCE, ROY G.
1913. Forestation of the sand hills of Nebraska and Kansas. U. S. Dept. Agr., Forest Serv. Bul. 121, 49 p., 1 fig., 13 pl.

BAUDISCH, FRIEDRICH.

(8) 1888. Ueber "Phytophthora omnivora" als Schädling des Buchenaufschlages. *In* Centbl. Gesam. Forstw., Jahrg. 14, Heft 8/9, p. 382–385.

(9) 1903. Notizen über Septoria parasitica R. H., Fusoma Pini R. H. und Allescheria Laricis R. H. *In* Centbl. Gesam. Forstw., Jahrg. 29, Heft 11, p. 461–464.

(10) BEINHART, E. G.
1918. Steam sterilization of seed beds for tobacco and other crops. U. S. Dept. Agr., Farmers' Bul. 996, 15 p., 4 fig.

(11) BEISSNER, LUDWIG.
1909. Handbuch der Nadelholzkunde. Aufl. 2, xvi, 742 p., illus. Berlin.

(12) BLACKMAN, V. H., and WELSFORD, E. J.
1916. Studies in the physiology of parasitism. II. Infection by Botrytis cinerea. *In* Ann. Bot., v. 30, no. 119, p. 389–398, pl. 10. Literature cited, p. 397.

(13) BOERKER, RICHARD H.
1916. Ecological investigations upon the germination and early growth of forest trees. *In* Nebr. Univ. Studies, v. 16, no. 1/2, p. 1–90, illus., 5 pl. Bibliography, p. 88–89.

(14) BOLLEY, H. L.
1901. Flax wilt and flax sick soil. N. Dak. Agr. Exp. Sta. Bul. 50, p. 27–58, [17] fig.

(15) BROWN, JAMES.
1894. The Forester . . . ed. 6 enl., ed. by John Nesbit. Vol. 2. Edinburgh, London.

(16) BROWN, WILLIAM.
1916. Studies in the physiology of parasitism. III. On the relation between the "infection drop" and the underlying host tissue. *In* Ann. Bot., v. 30, no. 119, p. 399–406.

(17) BRUCHMANN, H.
1885. Das Prothallium von Lycopodium. *In* Bot. Centbl., Bd. 21, No. 10, p. 309–313.

(18) BRYANT, ARTHUR.
1871. Forest Trees for Shelter, Ornament, and Profit . . . 247 p., [12] pl. New York.

(19) BUCKINGHAM, EDGAR.
1904. Contributions to our knowledge of the aeration of soils. U. S. Dept. Agr., Bur. Soils Bul. 25, 52 p.

(20) BURGER, O. F.
1913. Lettuce drop. Fla. Agr. Exp. Sta. Bul. 116, p. [25]–32, 3 fig.

(21) BURGSDORF, FRIEDRICH AUGUST LUDWIG VON.
1783. Versuch einer vollständigen Geschichte vorzüglicher Holzarten . . . Bd. 1, Theil 1. Berlin.

(22) BUSSE, W., PETERS, L., and ULRICH, P.
1911. Ueber das Vorkommen von Wurzelbranderregern im Boden. *In* Arb. K. Biol. Anst. Land- u. Forstw., Bd. 8, Heft 2, p. 260–302. (Untersuchungen über die Krankheiten der Rüben, von W. Busse. 6.)

BUTLER, E. J.
(23) 1907. An account of the genus Pythium and some Chytridiaceæ. *In* Mem. Dept. Agr. India, Bot. Ser., v. 1, no. 5, 160 p., 10 pl. Literature, p. 142–147.

(24) 1913. Pythium debaryanum Hesse. *In* Mem. Dept. Agr. India, Bot. Ser., v. 5, no. 5, p. 262–267, pl. 5. (Studies in Peronosporaceæ, by E. J. Butler and G. S. Kulkarni.)

BÜTTNER, G.
(25) 1903. Über das Absterben junger Nadelholzpflanzen im Saatbeete. *In* Mitt. Deut. Dendrol. Gesell., No. 12, p. 81–82.

(26) 1906. Etwas über den Keimlingspilz, Fusoma parasiticum v. Tub. *In* Mitt. Deut. Dendrol. Gesell., No. 15, p. 232.

(27) BYARS, L. P., and GILBERT, W. W.
1919. Soil disinfection by hot water to control the root-knot nematode and parasitic soil fungi. (Abstract.) *In* Phytopathology, v. 9, no. 1, p. 49.

(28) CLINTON, G. P.
1913. Report of the botanist, 1911 and 1912. *In* Conn. Agr. Exp. Sta., 36th Ann. Rpt. 1911–1912, pt. 5, p. [341]–453, pl. 17–28.

(29) COOK, MEL T., and HELYAR, J. P.
1915. Diseases of grains and forage crops. N. J. Agr. Exp. Sta., Circ. 51, 8 p.

(30) DAVENPORT, E.
1907. Principles of Breeding . . . xiii, 727 p., illus. Boston, New York.

(31) DAWSON, JACKSON.
1885. The propagation of trees and shrubs from seed. *In* Trans. Mass. Hort. Soc., 1885, pt. 1, p. 145–166.

DUGGAR, B. M., and STEWART, F. C.

(32) 1901. The sterile fungus Rhizoctonia as a cause of plant diseases in America. N. Y. (Cornell) Agr. Exp. Sta. Bul. 186, p. 51–76, [fig.] 15–23.

(33) 1909. Fungous Diseases of Plants . . . xii, 508 p., illus., pl. Boston, New York.

(34) 1916. Rhizoctonia solani in relation to the "Mopilz" and the "Vermehrungspilz." *In* Ann. Mo. Bot. Gard., v. 3, no. 1, p. 1–10. Literature cited, p. 9–10.

EDGERTON, C. W.

(35) 1915. Effect of temperature on Glomerella. *In* Phytopathology, v. 5, no. 5, p. 247–259, 4 fig.

(36) 1915. A new method of selecting tomatoes for resistance to the wilt disease. *In* Science, n. s., v. 42, no. 1095, p. 914–915.

EDSON, H. A.

(37) 1915. Histological relations of sugar-beet seedlings and Phoma betae. *In* Jour. Agr. Research, v. 5, no. 1, p. 55–58, pl. 1–2.

(38) 1915. Seedling diseases of sugar beets and their relation to root-rot and crown-rot. *In* Jour. Agr. Research, v. 4, no. 2, p. 135–168, pl. 16–26. Literature cited, p. 165–168.

(39) 1915. Rheosporangium aphanidermatus, a new genus and species of fungus parasitic on sugar beets and radishes. *In* Jour. Agr. Research, v. 4, no. 4, p. 279–292, pl. 44–48.

(40) ——— and SHAPOVALOV, M.
1918. Potato-stem lesions. *In* Jour. Agr. Research, v. 14, no. 5, p. 213–220, pl. 24–26.

(41) FAWCETT, H. S.
1909. Report of plant pathologist. *In* Fla. Agr. Exp. Sta. Rpt. 108/09, p. xlvi–lxii, fig. 7–12.

(42) FISCHER, ALFRED.
1892. Die Pilze Deutschlands, Oesterreichs und der Schweiz. IV. Abtheilung: Phycomycetes. *In* Rabenhorst, L., Kryptogamen-Flora . . . Aufl. 2, Bd. 1, Pilze. Leipzig.

(43) FRED, E. B.
1916. Relation of green manures to the failure of certain seedlings. *In* Jour. Agr. Research, v. 5, no. 25, p. 1161–1176, pl. 83–84. Literature cited, p. 1175–1176.

(44) GALLOWAY, B. T.
1893. Report of the Chief of the Division of Vegetable Pathology. *In* U. S. Dépt. Agr., 1892, p. 215–246, 1 fig., 4 pl.

(45) GARDNER, JOHN.
1890. [Damping-off.] *In* Amer. Gard., v. 11, no. 6, p. 347–348.

(46) GIFFORD, C. M.
1911. The damping-off of coniferous seedlings. Vt. Agr. Exp. Sta. Bul. 157, p. 143–171, 10 fig., 4 pl. Bibliography, p. 171.

(47) GILBERT, W. W.
1909. The root-rot of tobacco caused by Thielavia basicola. U. S. Dept. Agr., Bur. Plant Indus. Bul. 158, 55 p., 5 pl. Bibliography, p. 44–48.

(48) GLOYER, W. O.
1913. The efficiency of formaldehyde in the treatment of seed potatoes for Rhizoctonia. N. Y. State Agr. Exp. Sta. Bul. 370, p. 417–431.

(49) GOEBEL, K.
1887. Ueber Prothallien und Keimpflanzen von Lycopodium inundatum. *In* Bot. Ztg., Jahrg. 45, No. 11, p. 161–168; No. 12, p. 177–190, pl. 2.

GÜSSOW, H. T.
(50) 1912. Report of the Dominion botanist. *In* Canada Exp. Farms Rpts., 1911/12, p. 191–215, 4 fig., pl. 6–7.

(51) 1917. The pathogenic action of Rhizoctonia on potato. *In* Phytopathology, v. 7, no. 3, p. 209–213, 1 fig.

HALSTED, BYRON D.
(52) 1892. Fungous troubles in the cutting beds. *In* Gard. and Forest, v. 5, no. 209, p. 91–92.

(53) 1893. Fungi injurious to weed seedlings. *In* N. J. Agr. Exp. Sta. 13th Ann. Rpt., 1891, p. 342–345.

(54) HARRIS, J. ARTHUR.
1915. The value of inter-annual correlations. *In* Amer. Nat., v. 49, no. 587, p. 707–712.

HARTIG, R.
(55) 1876. Die Buchencotyledonen-Krankheit. *In* Ztschr. Forst- u. Jagdw., Bd. 8, p. 117–123.

(56) 1879. Die Buchenkeimlingskrankheit erzeugt durch Phytophthora fagi M. *In* Forstw. Centbl., Jahrg. 23, Heft 3, p. 161–170.

(57) 1880. Der Buchenkeimlingspilz, Phytophthora (Peronospora) fagi M. *In* Unters. Forstbot. Inst., München, [Bd.] 1, p. 33–57, pl. 3.

(58) 1880. Der Ahornkeimlingspilz, Cercospora acerina M. *In* Unters. Forstbot. Inst., München, [Bd.] 1, p. 58–62, pl. 4.

(59) 1883. Beschädigung der Nadelholzsaatbeete durch Phytophthora omnivora (Fagi). *In* Forstw. Centbl., Jahrg. 27, Heft 12, p. 593–596.

(60) 1892. Ein neuer Keimlingspilz. *In* Forstl. Naturw. Ztschr., Jahrg. 1, Heft 11, p. 432–436, 4 fig.

(61) 1894. Text-Book of the Diseases of Trees. Trans. by William Somerville . . . rev. and ed., by H. Marshall Ward. xvi, 331 p., illus. London.

HARTLEY, CARL.
(62) 1910. Notes on some diseases of coniferous nursery stock. (Abstract.) *In* Science, n. s., v. 31, no. 799, p. 639.

(63) 1912. Use of soil fungicides to prevent damping-off of coniferous seedlings. *In* Proc. Soc. Amer. Foresters, v. 7, no. 1, p. 96–99.

(64) 1913. The blights of coniferous nursery stock. U. S. Dept. Agr. Bul. 44, 21 p.

(65) ——— and MERRILL, THEODORE C.
1914. Preliminary tests of disinfectants in controlling damping-off in various nursery soils. *In* Phytopathology, v. 4, no. 2, p. 89–92.

(66) ——— and BRUNER, S. C.
1915. Notes on Rhizoctonia. *In* Phytopathology, v. 5, no. 1, p. 73–74.

(67) HARTLEY, CARL, and PIERCE, ROY G.
1917. The control of damping-off of coniferous seedlings. U. S. Dept. Agr. Bul. 453, 20 p., 2 pl.

(68) ——— MERRILL, T. C., and RHOADS, ARTHUR S.
1918. Seedling diseases of conifers. *In* Jour. Agr. Research, v. 15, no. 10, p. 521–558, pl. B. Literature cited, p. 556–558.

(69) ——— and HAHN, GLENN G.
1919. Oomycetes parasitic on pine seedlings. (Abstract.) *In* Phytopathology, v. 9, no. 1, p. 50.

(70) HAWKINS, LON A.
1916. The disease of potatoes known as "leak." *In* Jour. Agr. Research, v. 6, no. 17, p. 627–640, 1 fig., pl. 90. Literature cited, p. 639.

(71) ——— and HARVEY, RODNEY B.
1919. Physiological study of the parasitism of Pythium debaryanum Hesse on the potato tuber. *In* Jour. Agr. Research, v. 18, no. 5, p. 275–298, 2 fig., pl. 35–37. Literature cited, p. 295–297.

(72) HENDERSON, M. P.
1918. The black-leg disease of cabbage caused by Phoma lingam (Tode) Desmaz. *In* Phytopathology, v. 8, no. 8, p. 379–431, 10 fig. Literature cited, p. 431.

(73) HESS, RICHARD.
1900. Der Forstschutz. Aufl. 3, Bd. 2. Leipzig.

(74) HESSE, RUDOLPH.
1874. Pythium debaryanum, ein endophytischer Schmarotzer. 76 p., 2 pl. Halle. Inaug.-Dissert., Göttingen.

(75) HILTNER, L.
1902. Die Keimungsverhältnisse der Leguminosensamen und ihre Beeinflussung durch Organismenwirkung. *In* Arb. K. Gsndhtsamt., Biol. Abt., Bd. 3, Heft 1, p. 1–102, 3 fig.

(76) ——— and PETERS, L.
1904. Untersuchungen über die Keimlingskrankheiten der Zucker- und Runkelrüben. *In* Arb. K. Gsndhtsamt., Biol. Abt., Bd. 4, Heft 3, p. 207–253.

(77) HOFMANN, JULIUS V.
1912. Aerial isolation and inoculation with Pythium debaryanum. *In* Phytopathology, v. 2, no. 6, p. 273.

(78) HORNE, WILLIAM T.
1907. Algunos inconvenientes de los Semilleres de Tabaco. Cuba Estac. Cent. Agron. Circ. 28, 13 p.

(79) JACZEWSKI, A. DE.
1911. O gribnekh bolies makh liesnekh porod i mierakh borbi s nimi. (Les maladies cryptogamiques des essences forestières, et la façon de les combattre.) [Russia.] Biuro po Mikologhii Etiopatologhii. (Bureau de Mycologie et de Phytopathologie.) St. Petersbourg. (Not seen. Title from Just's Bot. Jahresber., Jahrg. 39 (1911), Abt. 1, Heft 3, p. 1249. 1913.)

(80) JOHNSON, EDWARD C.
1914. A study of some imperfect fungi isolated from wheat, oat, and barley plants. *In* Jour. Agr. Research, v. 1, no. 6, p. 475–490, pl. 62–63. Literature cited, p. 487–489.

JOHNSON, JAMES.

(81) 1914. The control of diseases and insects of tobacco. Wis. Agr. Exp. Sta. Bul. 237, 34 p., 9 fig. Literature cited, p. 60–61.

(82) 1914. The control of damping-off disease in plant beds. Wis. Agr. Exp. Sta. Research Bul. 31, p. 29–61, 12 fig.

(83) JONES, L. R.
1908. The damping-off of coniferous seedlings. *In* Vt. Agr. Exp. Sta. 20th Ann. Rpt. 1906/07, p. 342–347.

(84) KING, WILLFORD I.
1912. The Elements of Statistical Method. xvi, 250 p., 26 fig. New York.

(85) KNECHTEL, WILHELM K.
1914. Pythium de Baryanum Hesse ca provacator al unei boale de rasad de tutun. Supl. Bulet. Reg. Monop. Statul., Bucuresti, 48 p., pl. 5–7. (Abstract *in* Ztschr. Pflanzenkrank., Bd. 28, p. 61–62. 1918.)

(86) LINDAU, G.
1908. Die pflanzlichen Parasiten. *In* Sorauer, Paul, Handbuch der Pflanzenkrankheiten. Aufl. 3, Bd. 2. Berlin.

(87) LOHDE, [G.]
1874. Ueber einige neue parasitische Pilze. *In* Tagebl. 47, Versamml. Deut. Naturf. u. Arzte, Breslau, 1874, p. 203–206.

(88) MCCLATCHIE, ALFRED JAMES.
1902. Eucalypts cultivated in the United States. U. S. Dept. Agr., Bur. Forestry Bul. 35, 106 p., 91 pl. Bibliography, p. 99–101.

(89) MIYAKE, KIICHI.
1901. The fertilization of Pythium debaryanum. *In* Ann. Bot., v. 15, no. 60, p. 663–667, pl. 36. List of papers cited, p. 665–666.

(90) MÖLLER, F.
1909. Kupfervitriol gegen die Vermehrungspilz. *In* Möller's Deut. Gärt. Ztg., Jahrg. 24, No. 7, p. 77.

(91) MUTH, FRANZ.
1908. Ueber die Infektion von Samereien im Keimbett. *In* Jahresber. Angew. Bot., Jahrg. 5 (1907), p. 49–82.

NEGER, F. W.

(92) 1909. Beobachtungen und Erfahrungen über Krankheiten einiger Gehölzsamen. *In* Tharand. Forstl. Jahrb., Bd. 60, p. 222–252, 4 fig.

(93) 1910. Pathologische Mitteilungen aus dem Botanischen Institut der Kgl. Forstakademie Tharandt. III. Ueber bemerkenswerte, in sächsischen Forsten auftretende Baumkrankheiten. *In* Tharand. Forstl. Jahrb. Bd. 61, Heft 2, p. 141–167, 13 fig.

(94) ——— and BÜTTNER, G.
1907. Ueber Erfahrungen mit der Kultur fremdländischer Koniferen im akademischen Forstgarten zu Tharandt. *In* Naturw. Ztschr. Land- u. Forstw., Jahrg. 5, Heft 4, p. 204–210.

(95) NESTLER, A.
1899. Ueber das Vorkommen von Pilzen in Wachholderbeeren. *In* Ber. Deut. Bot. Gesell., Bd. 17, Heft 8, p. 320–325, pl. 25.

(96) NORTON, J. B.
1913. Methods used in breeding asparagus for rust resistance. U. S. Dept. Agr., Bur. Plant Indus. Bul. 263, 60 p., 4 fig., 18 pl.

(97) PEARSON, G. W.
1906. Two diseases of pines. *In* 37th Ann. Rpt. Nebr. Hort. Soc., 1906, p. 230–232.

(98) PELTIER, GEORGE L.
1916. Parasitic Rhizoctonias in America. Ill. Agr. Exp. Sta. Bul. 189, p. 283–390, 24 fig. Bibliography, p. 386–390.

PETERS, L.
(99) 1910. Eine häufige Stecklingskrankheit der Pelargonien. *In* Gartenflora, Jahrg. 59, Heft 10, p. 209–213, pl. 1582.

(100) 1911. Ueber die Erreger des Wurzelbrandes. *In* Arb. K. Biol. Anst. Land-u. Forstw., Bd. 8, Heft 2, p. 211–259, 12 abb. (Untersuchungen über die Krankheiten der Rüben, von W. Busse. 5.)

(101) PETTIS, CLIFFORD ROBERT.
1909. Problems in nursery practice. *In* Proc. Soc. Amer. Foresters, v. 4, no. 1, p. 42–49.

(102) PIERCE, ROY G., and HARTLEY, CARL.
1919. Relative importance of Pythium and Rhizoctonia in coniferous seed beds. (Abstract.) *In* Phytopathology, v. 9, no. 1, p. 50.

(103) POOLE, R. F.
1918. Report of celery investigation. *In* N. J. Agr. Exp. Sta. 38th Ann. Rpt. 1916/17, p. 536–539.

(104) PRILLIEUX, ED.
1895. Maladies des Plantes agricoles et des Arbres fruitiers et forestiers causées par des Parasites végétaux. T. 1. Paris.

(105) RANKIN, W. HOWARD.
1918. Manual of Tree Diseases. xx, 398 p., 70 fig. New York.

(106) RATHBUN, ANNIE E.
1918. The fungous flora of pine seed beds. *In* Phytopathology, v. 8, no. 9, p. 469–483. Literature cited, p. 483.

REINKING, OTTO A.
(107) 1918. Philippine economic-plant diseases. *In* Philippine Jour. Sci., v. 13, sect. A, no. 4–5, p. 165–274, 43 fig., 22 pl.

(108) 1919. Philippine plant diseases. *In* Phytopathology, v. 9, no. 3, p. 114–140.

RETAN, GEORGE A.
(109) 1915. Charcoal as a means of solving some nursery problems. *In* Forestry Quart., v. 13, no. 1, p. 25–30.

(110) 1918. Nursery practice in Pennsylvania. *In* Jour. Forestry, v. 16, no. 7, p. 761–769.

(111) ROGERS, STANLEY S.
1913. The culture of tomatoes in California, with special reference to their diseases. Cal. Agr. Exp. Sta. Bul. 239, p. 591–617, 13 fig.

(112) ROLFS, F. M.
1915. Angular leaf-spot of cotton. S. C. Agr. Exp. Sta. Bul. 184, 30 p., 9 pl. Literature cited, p. 30.

(113) ROLFS, P. H.
1913. Tomato diseases. Fla. Agr. Exp. Sta. Bul. 117, p. [33]–48, fig. 4–5.

(114) ROSENBAUM, J.
1917. Studies of the genus Phytophthora. *In* Jour. Agr. Research, v. 8, No. 7, p. 233–276, 13 fig., pl. 71–77. Literature cited, p. 273–276.

RUHLAND, W.
(115) 1908. Beitrag zur Kenntniss des sog. "Vermehrungspilzes." *In* Arb. K. Biol. Anst. Land- u. Forstw., Bd. 6, Heft 1, p. 71–76, 3 abb.

(116) 1908. Beitrag zur Kenntniss des sog. "Vermehrungspilzes." *In* Mitt. K. Biol. Anst. Land- u. Forstw., Heft 6, p. 24–25.

(117) SADEBECK, R.
1874. Ueber Pythium Equiseti. *In* Verhandl. Bot. Ver. Brandenb., Jahrg. 16, p. 116–124.

(118) SAXTON, W. T.
1913. The classification of conifers. *In* New Phytol., v. 12, no. 7, p. 242–262, 1 fig. List of references, p. 259–262.

(119) SCHAAF, MARCUS.
1915. Report of the State forester. *In* Rpt. Mich. Pub. Domain Com., 1913/14, p. 60–106, [27] fig.

(120) SCHELLE, E.
1909. Die winterharten Nadelhölzer Mitteleuropas . . . viii, 356 p., 173 fig., map. Stuttgart.

(121) SCHOLZ, EDUARD.
1897. Rhizoctonia strobi, ein neuer Parasit der Weymouthskiefer. *In* Verhandl. K. K. Zool. Bot. Gesell. Wien, Bd. 47, Heft. 8, p. 541–557, 6 abb.

(122) SCHRAMM, R.
1904. Zum Absterben junger, unverholzter Nadelholzpflanzen im Saatbeet. *In* Mitt. Deut. Dendrol. Gesell., No. 13, p. 203.

(123) SCOTT, CHARLES A.
1917. A practical method of preventing the damping-off of coniferous seedlings. *In* Jour. Forestry, v. 15, no. 2, p. 192–196, 2 pl.

(124) SECRIST, HORACE.
1917. An Introduction to Statistical Methods . . . 482 p., 28 pl. New York.

(125) SELBY, A. D.
1910. A brief handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 214, p. 307–456, i–vii, 105 fig. Literature of plant diseases, p. i–vii.

(126) ——— and MANNS, THOMAS F.
1909. Studies in diseases of cereals and grasses. Ohio Agr. Exp. Sta. Bul. 203, p. 187–236, 7 fig., 14 pl.

SHERBAKOFF, C. D.
(127) 1916. Report of the assistant plant pathologist. *In* Fla. Agr. Exp Sta. Rpt. 1914/15, p. xciv–xcviii.

(128) 1917. Report of the associate plant pathologist. *In* Fla. Agr. Exp. Sta. Rpt. 1915/16, p. 80R–98R, fig. 12–16.

(129) 1917. Some important diseases of truck crops in Florida. Fla. Agr. Exp. Sta. Bul. 139, p. [191]–277, fig. 75–112.

(130) SMITH, RALPH E.
1909. Report of the plant pathologist and superintendent of southern California stations, July 1, 1906, to June 30, 1909. Cal. Agr. Exp. Sta. Bul. 203, 63 p., 23 fig.

(131) Smith, Ralph E., and Smith, Elizabeth H.
1911. California plant diseases. Cal. Agr. Exp. Sta. Bul. 218, p. [1039]–1193, 102 fig.

(132) Somerville, William.
1909. Rhizoctonia violacea, causing a new disease of trees. *In* Quart. Jour. Forestry, v. 3, no. 2, p. 134–135.

(133) Sorauer, P.
1899. Der "Vermehrungspilz." *In* Ztschr. Pflanzenkrank., Bd. 9, Heft 6, p. 321–328, pl. 6.

(134) Spalding, V. M.
1899. The white pine (Pinus strobus Linnæus) rev. and enl. by B. E. Fernow. U. S. Dept. Agr., Div. Forestry Bul. 22, 185 p., 40 fig., 13 pl.

Spaulding, Perley.
(135) 1907. A blight disease of young conifers. *In* Science, n. s., v. 26, no. 659, p. 220–221.

(136) 1908. The treatment of damping-off in coniferous seedlings. U. S. Dept. Agr., Bur. Plant Indus. Circ. 4, 8 p.

(137) 1914. The damping-off of coniferous seedlings. *In* Phytopathology, v. 4, no. 2, p. 73–88, 2 fig., pl. 6. Bibliography, p. 85–87.

(138) Taylor, Minnie W.
1917. Preliminary report on the vertical distribution of Fusarium in soil. *In* Phytopathology, v. 7, no. 5, p. 374–378.

(139) Tillotson, C. R.
1917. Nursery practice on the National Forests. U. S. Dept. Agr. Bul. 479, 86 p., 6 fig., 22 pl.

Tubeuf, C. von.
(140) 1888. Eine neue Krankheit der Douglastanne. *In* Bot. Centbl., Bd. 33, No. 11, p. 347–348.

(141) 1901. Fusoma-Infektionen. *In* Arb. K. Gsndhtsamt., Biol. Abt., Bd. 2, Heft 1, p. 167–168, 2 fig.

(142) 1914. Hitzetot und Einschnürungskrankheiten der Pflanzen. *In* Naturw. Ztschr. Forst- u. Landw., Jahrg. 12, Heft 1, p. 19–36, 4 fig.

(143) Voglino, Piero.
1908. I funghi parassiti delle piante osservati nella Provincia di Torino e regione vicine nel 1907. *In* Ann. R. Accad. Agr. Torino, v. 50 (1907), p. 247–271.

(144) Ward, H. Marshall.
1883. Observations on the genus Pythium (Pringsh.). *In* Quart. Jour. Micros. Sci., n. s., v. 23, no. 92, p. 487–515, pl. 34–36.

(145) Watson, B. M., Jr.
1890. [Damping-off.] *In* Amer. Gard., v. 11, no. 6, p. 348.

(146) Weston, William H.
1918. The development of Thraustotheca, a peculiar water-mould. *In* Ann. Bot., v. 32, no. 125, p. 155–173, 2 fig., pl. 4–5. Literature cited, p. 171–172.

(147) Wilson, Guy West.
1914. Studies in North American Peronosporales. V. A review of the genus Phytophthora. *In* Mycologia, v. 6, no. 2, p. 54–83, pl. 119. Bibliography, p. 80–82.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 935

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C. ▼ March 14, 1921

THE DISTRIBUTION OF NORTHWESTERN BOXED APPLES.

By C. W. Kitchen, *Specialist in Market News, Fruits and Vegetables;* E. M. Seifert, Jr., *Assistant in Market Surveys;* and Mary B. Hall, *Clerk.*

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INTRODUCTION.

The apple industry in the Pacific Northwest has developed rapidly since 1900. In the fall of 1915, at the request of a number of representative growers and shippers of apples in the States of Washington, Oregon, Idaho, and Montana, the Bureau of Markets began a systematic collection of statistical data relevant to distribution, prices, and other general factors influencing the marketing of apples from this territory. Arrangements were made with the railroads serving these States by which copies of waybills covering car-lot shipments of apples in 1915–16 were furnished the Bu-

reau. Shippers furnished copies of invoices and sales records. Beginning with the 1916 season, telegraphic reports of shipments were received daily from division superintendents of common carriers serving the Pacific Northwest, and shippers reported their f. o. b. and contract sales each day such sales were made. From data thus obtained a summary of the distribution of several of the principal varieties and their seasonal price trends has been compiled.[1]

Each season since the fall of 1916 the Bureau has issued daily market reports from Spokane showing the number of cars shipped from the Pacific Northwest and in the United States as a whole. In addition, primary destinations of Northwest shipments, the jobbing prices prevailing in the principal consuming and distributing markets of the United States, and the f. o. b. prices at several of the principal points of shipment in competing districts were shown. These reports were mailed daily to growers and shippers. The number of individuals served has varied from season to season, with a maximum of approximately 4,000.

Data gathered by these means and presented in this bulletin do not cover every car that was shipped, but are believed to be representative and sufficiently comprehensive and complete to justify their use as a basis for a statistical analysis of the marketing of the greater part of the boxed apple crop of the United States.

PRODUCTION.

The districts of the Pacific Northwest now prominent in apple production are of recent origin compared with the established districts in the eastern States. They cover well-defined areas in each State, where soil and climatic conditions are particularly favorable to apple production. The tree census of the Wenatchee district taken by the Wenatchee North Central Washington Growers' League in 1915 showed less than 10 per cent of the apple trees to be 10 or more years of age. This district was then, and still is, the largest in point of apple production in the Pacific Northwest, and may in point of development be considered as representative of the entire section.

The principal districts,[2] in the order of their importance in production, are the Wenatchee Valley, Yakima Valley, Hood River district, Spokane district, Southern Idaho district, Walla Walla-

[1] See Exhibit No. 1, p. 11.

[2] A complete list of billing stations for the entire Pacific Northwest segregated into districts and showing the 1919–20 shipments from each station will be found in Exhibit No. 2, p. 11.

Milton-Freewater district, Rogue River Valley, Western Oregon, and the Bitter Root Valley of Montana.

The Wenatchee Valley in 1919–20 shipped approximately 33 per cent of the total movement from the Pacific Northwest, Yakima Valley about 30 per cent, and Hood River district and Southern Idaho about 10 per cent each. Spokane contributed about 8 per cent, and the Walla Walla-Milton-Freewater district about half of the number of cars shipped from the Spokane Valley. Montana, with an increased production over preceding years, is credited with a little less than 2 per cent of the total Northwest shipments.

The first commercial shipments of apples from the Northwest were made in 1900. With the extension of irrigation work the development of the industry was steady and rapid and land values advanced with increased production.

The Bureau of Crop Estimates placed the 1914 total production in the Pacific Northwest at about one-sixteenth of the total production of the United States. By 1916 the proportion had increased to almost one-sixth, and in 1919 more than one-third of the apple crop of the country was credited to the four States of Washington, Oregon, Idaho, and Montana.

Commercial production, estimated by Bureau of Crop Estimates.

	United States.	32 barrel States.	9 box [1] States.	4 Pacific Northwest box [1] States.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*
1916	25,059,000	19,102,000	5,957,000	4,301,000
1917	22,467,000	13,914,000	8,563,000	6,313,000
1918	24,743,000	17,640,000	7,103,000	5,154,000
1919	26,174,000	14,353,000	11,821,000	9,121,000
1920	34,281,000	26,593,000	7,688,000	6,568,000

[1] Three boxes per barrel.

Carlot shipments [3] from the Pacific Northwest increased steadily, and during the 1916–17 season were somewhat less than one-third of the total for the country. Reports of shipments during the 1919–20 season show that more than 40 per cent moved from the Pacific Northwest.

Reports of sales indicate that more than 100 varieties are produced in and sold from this section, but each year sees an increasingly large percentage of a few of the more popular types, as shown in the following table:

[3] See Exhibit No. 3, p. 16.

Percentage of leading varieties of apples produced.

Variety.	1915–16		1918–19		1919–20	
	Cars.	Per cent.	Cars.	Per cent.	Cars.	Per cent.
Winesap	2,614	22.8	6,129	31.8	8,319	25.0
Jonathan	2,430	21.2	2,564	13.3	5,989	18.0
Rome Beauty	1,238	10.8	1,041	5.4	4,325	13.0
Spitzenberg	802	7.0	1,022	5.3	2,994	9.0
Yellow Newtown	711	6.2	946	4.9	2,328	7.0
Delicious	333	2.9	713	3.7	1,663	5.0
Miscellaneous	3,337	29.1	6,861	[1] 35.6	7,652	23.0
Total	11,465	100.0	19,276	100.0	33,270	100.0

[1] The percentage of miscellaneous varieties shown for the 1918–19 season includes cars of mixed varieties that could not be segregated. A number of these cars contained some apples of the Winesap, Jonathan, Rome Beauty, Spitzenberg, Yellow Newtown, and Delicious varieties.

Conditions peculiar to the different districts have made necessary specialization in varieties grown. In southern Idaho the bulk of the crop is composed of Winesap, Rome Beauty, and Jonathan apples. In Hood River Valley Yellow Newtowns and Spitzenbergs predominate, with a very small percentage of other varieties. The Yakima Valley grows a large percentage of Winesaps and Jonathans. The Wenatchee Valley also produces many of the Winesap variety, and the Jonathan and Delicious together about equal the Winesaps. The Rome Beauty predominates in the Walla Walla and Spokane Valleys. Growers in the Bitter Root Valley specialize largely on the McIntosh.

The following varieties were not grown in sufficiently large volume to show the relative percentages: Arkansas Black, Ben Davis, Gravenstein, Grimes, King David, McIntosh, Ortley, Stayman, Winesap, Wagener, White Pearmain, Banana.

PREPARATION FOR MARKET.

Orchards throughout the Pacific Northwest have been kept in a state of high cultivation and every known means is employed to grow and develop trees that will produce the largest possible crop of highly colored fruit. The trees are pruned to a shape that facilitates spraying and picking. Rigid grading rules, strictly enforced, have resulted in an excellent pack.[4] Frequent changes have been made in these rules, but the general tendency has been toward improvement.

As production increases in volume harvesting, packing, and shipping problems become increasingly difficult. A very large proportion of the labor employed during this period is migratory and temporary. This is especially true of sorters, packers, and those employed in loading the cars. They move from the south to the north as the various fruit crops in the West are harvested.

[4] Grading rules adopted for Washington will be found in Exhibit No. 4, p. 17.

Standardization in packing-house methods has not been extensively applied. Modern appliances for handling the fruit, such as sizing machines and power and gravity conveyors, are now generally used. Apples are packed at the orchards and in central or community packing houses operated by shipping organizations. The proportion packed in the houses of the latter type has increased from about one-fourth of the crop in 1916 to approximately one-half in 1919.

Most of the fruit is packed into the three standard grades.[5] In the Extra Fancy and Fancy grades the fruit is wrapped with paper. Most shippers wrap the "G" grade, but "Jumble" and "face and fill" packs are also commonly used.

TRANSPORTATION AND STORAGE FACILITIES.

The long haul[6] from the producing areas in the Pacific Northwest to consuming centers makes the problem of transportation and storage most important. Transportation facilities have not kept pace with the rapidly increasing production, and many heavy losses to growers and shippers are attributed to the shortage of refrigerator equipment and insufficient storage space. This was especially true in the 1919–20 season. In 1915 the combined common and cold storages in producing districts could accommodate more than 60 per cent of the commercial production, but in the 1919–20 season there was capacity for approximately only 40 per cent of the fruit.

The unusually heavy production in 1919 with the combination of a short picking season and insufficient storage facilities caused an unprecedented congestion. Every available space was used for storing apples, and with the common storages and some cold storages packed with more than their designed capacity, proper ventilation and efficient handling were practically impossible. These congested conditions caused a very rapid maturing of much of the fruit, and heavy losses were sustained in consequent deterioration. Insufficient storage space and a shortage of cars in the fall cause much rehandling and add considerably to the cost of packing and shipping.

The railways, refrigerator-car lines, and the Bureau of Markets are making efforts to reduce waste in transit. The fruit is shipped mostly in refrigerator cars, and in the early fall and in the spring many shipments are made under ice. During periods of extreme low temperatures heaters are installed in the cars, but generally speaking most shipments are billed under ventilation. For short hauls and to Pacific coast points box cars are often used during the periods before and after extreme cold weather. In cases of great emergency during a car shortage shipments to eastern points are made in box cars, but in such cases they are usually accompanied by messengers

[5] See Exhibit No. 4, p. 17. [6] See Exhibit No. 1, p. 11.

and shipped under option 1. Shippers have the privilege of two options, known as option 1 and option 2. Shipped under option 1, a car moves at the shipper's risk; under option 2, at the carrier's risk. Prior to the fall of 1918 an average carload consisted of 630 boxes, but during the last two years 756 boxes to the car were considered a minimum load.

Storage facilities at points en route and at final destinations during recent seasons have been taxed to their limits. Eastern cold storages,[7] which include plants in the producing sections of New York State, where many boxed apples are stored, show by their reports on December 1 that they accommodated nearly twice as many cars in 1919 as in the previous year. At points in the Southern States[7] the increase over 1918 was about one-third. In the Middle Western States,[7] which include large centers of consumption and distribution, such as Chicago and Cincinnati, cold-storage holdings in 1919 doubled the 1918 holdings, and in the Southwestern States[7] holdings of boxed apples in cold storage were also greater than ever before.

RATE OF MOVEMENT.

The Pacific Northwest is now one of the most influential factors in the apple production of the country.[8] The final reports of apple shipments for the United States during the 1919–20 season show the heaviest movement in the history of the apple industry. The shipments from the Pacific Northwest, shown graphically[9] for the last four years, clearly indicate the influence of shipments from that section on the total movement of the country. The peak shipments for the United States and for the Pacific Northwest occur between the 15th and 25th of October. In 1919 the peak for the Northwest was reached on October 17, when 516 cars were billed.

Every effort is made to place as many apples as possible in storage at diverting points and final destinations before the extreme cold weather sets in, and it will be noticed that the movement is more uniform and gradual after the middle of December.

The movement during the 1919–20 season was restricted and hampered by the generally congested conditions and an insufficient number of cars. Usually, practically all early varieties are shipped before December, when the movement of Winesaps begins, but in the 1919–20 season the Rome Beauty and even some Jonathan and Delicious varieties were not shipped until January. The movement of Winesaps did not begin until very late, and comparatively large quantities of this variety were still in common storage after the latter part of March.

Washington has made a steady and rapid increase in production, and in 1919 this State alone produced more apples than any other

[7] See Exhibit No. 5, p. 19. [8] See Exhibit No. 6, p. 19. [9] See Exhibit No. 7, p. 20.

State in the history of the country. The production in Oregon also exceeded that of all previous years. Idaho [9] had a lean year in 1916 and again in 1918, but in 1917 had a comparatively heavy production, and in 1919 an unusually large yield. Montana [9] has developed slowly but gradually, and in 1919 practically doubled the previous year's shipments.

MARKETING METHODS.

Growers in the Pacific Northwest market the fruit through various agencies, the most important being cooperative selling organizations, local dealers, traveling cash buyers, and commission merchants.

The cooperative method generally consists of collective selling by hired representatives of one or more groups of producers, and practically every type of cooperative organization has been in operation. Local associations are formed, consisting of a single group of growers, who employ a manager to transact their business and sell the output. Federations of local groups also are formed, the managers of the local units acting merely as intermediaries between the central organization and the local unit. The central organizations practically control sales, collections, inspections, and advertising, thus facilitating standardization and specialization.

Local dealers purchase the fruit from growers, buying outright for cash or on contract. In some sections local merchants have developed a merchandising department and advance supplies and equipment to growers whose fruit they buy or handle on consignment.

A limited quantity of fruit is handled on a strictly consignment basis by resident dealers. Such dealers often operate packing houses where the fruit is graded, sized, and packed for a certain fixed charge per box, which includes box shook, materials, and labor. Cash sales to traveling or to resident buyers who represent firms in terminal markets are common. Some of these representatives also act as growers' agents and accept shipments on consignment.

Direct sales or sales through brokers to firms in consuming centers are usually made on an f. o. b. basis. Particularly was this true during the fall of 1919, when many of these firms contracted with northwestern shippers for future delivery. Various conditions make it necessary or desirable to roll a large number of loaded cars unsold. Usually these tramp cars are destined to territories that seem to promise the best returns and generally are sold when near to a market. Many of these sales are made through brokers.

Railroad records show that in 1915 there were 461 consignors of apples from the Pacific Northwest. This number has materially increased with the development of the industry.

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[9] See Exhibit No. 7, p. 20.

By-products plants are rapidly developing and are taking more and more of the inferior and cull fruit, thus making possible a higher standard of grades and larger net returns to the producers.

Increasing production and a constantly increasing number of shippers have resulted in active competition with resultant improvement in the marketing systems. As the volume increases and the marketing problems become more complex, the development of cooperation between growers' selling organizations and sales agents becomes almost imperative.

DISTRIBUTION.

Apples shipped from the Pacific Northwest enjoy a wider distribution[10] than any other commodity shipped from one section. Reports of destinations from carriers for the last five years show that 2,567 cities were used as primary destinations.[11] No attempt has been made to show final destinations because a large percentage of shipments were diverted and, unfortunately, such diversion information is not available. It is believed, however, that a sufficiently large number of primary destinations for the last five years were final destinations to make it fair to use this information as a basis for the further development of car-lot markets.

Telegraphic reports of shipments from the railroads during the 1919–20 season showed that about 1,400 cities received car-lot shipments of apples from the Pacific Northwest. It is safe to assume that complete diversion information would show a very much larger number of cities to which shipments were made.

New car-lot markets are being developed, particularly in the Central Plains, Middle Western, Southwestern, and Southeastern States. Not taking into account the shipments to the large markets and billings to Chicago and Minneapolis for consumption and diversion, small markets in these four sections of the country received about one-fourth of the 1919 northwestern crop. Diversions from Chicago and points west of Chicago would probably show that many more cars were finally received in the smaller markets, particularly in the Southwest and Southeast.

EXPORT SHIPMENTS.

Apples grown in the Pacific Northwest have been exported to practically all the continents on the globe, including Europe, Asia, Africa, Australasia, South America, and to the Dominion of Canada and Cuba. The development of steamship refrigerating facilities will doubtless increase these exports.

Exports[12] of apples from the United States during the 1916–17 season were reduced because of greatly increased risks and high war

[10] See Exhibit No. 8, p. 20. [11] See Exhibit No. 9, p. 20. [12] See Exhibit No. 10, p. 27.

insurance premiums. The use of shipping space for transporting war materials, together with measures taken by belligerent Governments to limit the importation of such commodities as apples also interfered. The exports during the following year were less than one-third of those during 1916–17. After the signing of the armistice there was an unusual export demand and shipments from the United States rapidly increased. The total for February, 1919, almost equals the entire 1917–18 exports.

Apple operators planned for even heavier exports during 1919–20, but, largely because of the very unfavorable rate of exchange, the exporting of apples became unprofitable and by February, 1920, shipments were reduced to the equivalent of 90,000 barrels for that month.

F. O. B. PRICES.

In making price studies[1] reports of sales from all classes of shippers were used. The price differentials between Extra Fancy, Fancy, and "C" grade are fairly uniform; therefore, only the Extra Fancy grade has been used and no sales of small sizes have been considered.

The price trend[1] for the last four years for f. o. b. sales at shipping points in the Pacific Northwest shows a steady advance. In 1916–17 there was a moderate range but a fairly uniform level to December. The 1917–18 season shows a comparatively small range in price but a generally higher level than the preceding season closing in March at prices somewhat above the opening. Prices opened at a higher level in 1918–19 than the closing of the previous season with gradual upward fluctuations from the first to the last of December, and then advanced rapidly to the close of the season in March to the highest prices ever realized in the Pacific Northwest.

The 1919–20 season opened at a price level of about $1 above the previous year's opening. Doubtless this can be attributed to the high prices which prevailed in the spring of 1919 and the unusual export demand, causing very active competition among apple buyers, who paid unusually high prices to growers. The great variance in the condition of the fruit was reflected in the wide price range which prevailed practically throughout the season. The variance was brought about by more or less careless handling, due largely to the pressure of getting the enormous crop picked, packed, and shipped or stored, inadequate and congested storage facilities which made much rehandling necessary, the October freeze, car shortages, and extremely cold weather in December. The top range of the price level continued fairly uniform until the latter part of February, when slow but steady advances finally closed in March at a little above the top opening prices. The extreme cold weather, a shortage

[1] See Exhibit No. 1, p. 11.

of cars, and a very limited demand from the latter part of November until the first part of January greatly restricted sales. During this period a very large percentage of the shipments were rolled unsold and many cars that moved in this way were forced on the large markets and sold finally at auction and on private sale at heavy discounts. Practically all sales of rollers were made at a lower figure than f. o. b. sales and showed a wider range. Reports from the large terminal markets showed price ranges of as much as $3 on the Extra Fancy grade. Freezing damage in transit was largely the cause of the very wide range in auction sales.

Although prices paid for apples in the fall of 1919 were higher than markets afterwards warranted and caused heavy losses to many operators, the average price at consuming centers was high for the season as a whole, considering the size of the crop.

As a brief summing up of the whole question of marketing northwestern boxed apples, it may be said that the present proportions of the industry have been made possible only by the progressive spirit by which it is characterized.

In the establishment of standards for color full advantage has been taken of the fact that a large percentage of well-colored specimens is usually produced in the Northwest. The market value of the fruit has been enhanced in this way. The State governments have been active in guarding against the shipment of inferior fruit and dishonest packs, so that the northwestern crop as a whole has been handled and marketed in general conformity to more uniform and rigid standards than have prevailed in other sections of equally heavy production. There is perhaps no more striking proof than is here afforded of the dominating importance of standardization as a factor in the successful large scale marketing of perishable farm products.

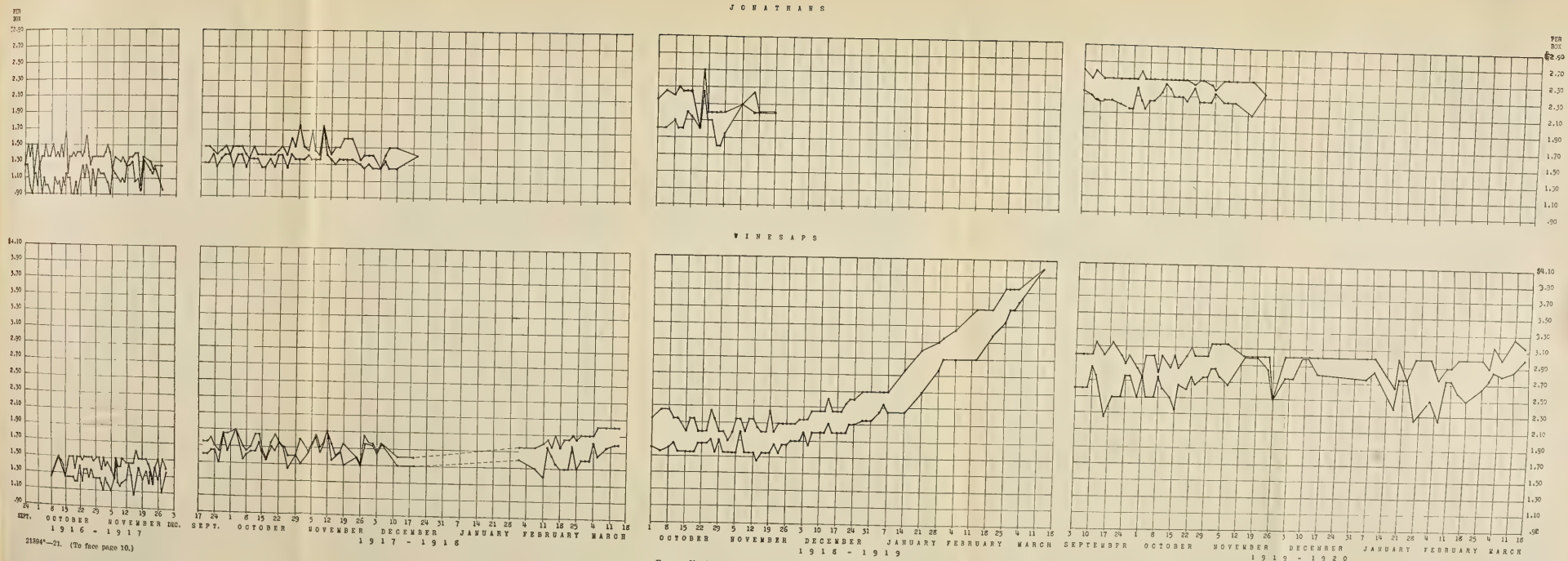


EXHIBIT No. 1.—F. o. b. prices of Northwestern boxed apples.

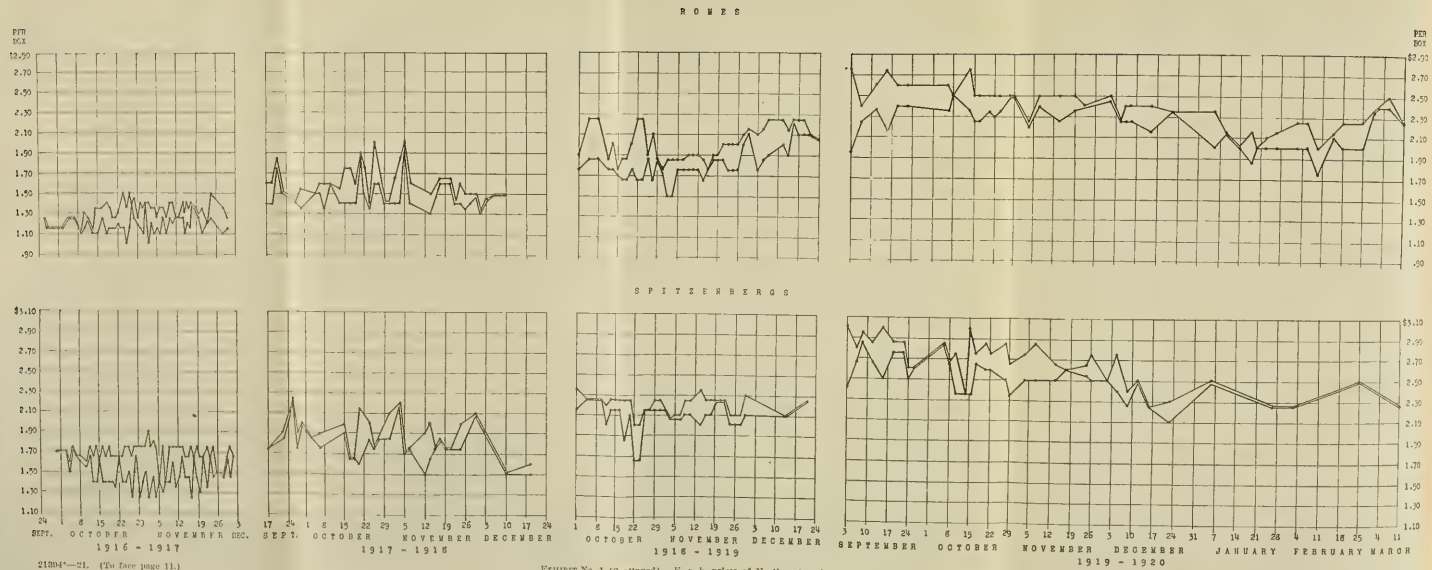


EXHIBIT No. 1 (Continued).—F. o. b. prices of Northwestern boxed apples.

APPENDIX.

Exhibit No. 1.

F. O. B. PRICES OF NORTHWESTERN APPLES.

(See folding charts.)

Extra Fancy Jonathan.—The prices shown on this chart represent sales f. o. b. shipping point. The data for 1916–17 represent 328 cars; 1917–18, 761 cars; 1918–19, 169 cars; 1919–20, 2,707 cars. Sales of the Extra Fancy grade only were used, and sales of tramp cars or rollers were not taken into consideration. The dots showing the price changes indicate the dates on which sales were recorded. Either no sales were made or no records were available on the dates between the dots.

Extra Fancy Winesap.—The prices shown on this chart represent sales f. o. b. shipping point. The data for 1916–17 represent 142 cars; 1917–18, 583 cars; 1918–19, 1,967 cars; 1919–20, 2,877 cars. Sales of the Extra Fancy grade only were used, and sales of tramp cars or rollers were not taken into consideration. The dots showing the price changes indicate the dates on which sales were recorded. Either no sales were made or no records were available on the dates between the dots.

Extra Fancy Rome Beauty.—The prices shown on this chart represent sales f. o. b. shipping point. The data for 1916–17 represent 95 cars; 1917–18, 228 cars; 1918–19, 260 cars; 1919–20, 1,268 cars. Sales of the Extra Fancy grade only were used, and sales of tramp cars or rollers were not taken into consideration. The dots showing the price changes indicate the dates on which sales were recorded. Either no sales were made or no records were available on the dates between the dots.

Extra Fancy Spitzenberg.—The prices shown on this chart represent sales f. o. b. shipping point. The data for 1916–17 represent 165 cars; 1917–18, 127 cars; 1918–19, 284 cars; 1919–20, 626 cars. Sales of the Extra Fancy grade only were used, and sales of tramp cars or rollers were not taken into consideration. The dots showing the price changes indicate the dates on which sales were recorded. Either no sales were made or no records were available on the dates between the dots.

Exhibit No. 2.

Pacific Northwest car-lot shipments of apples, 1919–20 season, by States, principal districts, and shipping stations.

SUMMARY, BY STATES.

	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Total.
Washington	32	167	1,763	9,401	6,770	1,787	1,854	1,881	1,930	1,094	473	16	27,168
Oregon	2	9	195	1,354	1,478	781	798	406	232	108	80	.....	5,443
Idaho	4	5	542	1,767	872	229	192	193	113	20	6	.....	3,943
Montana	.....	23	108	269	73	8	5	4	5	5	.....	.....	500
Total	38	204	2,608	12,791	9,193	2,805	2,849	2,484	2,280	1,227	559	16	37,054

Pacific Northwest car-lot shipments of apples, 1919–20 season, by States, principal districts, and shipping stations—Continued.

SUMMARY, BY DISTRICTS.

	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Total.
Wenatchee Valley district	3	46	633	3,773	3,438	827	877	799	916	776	40	------	12,128
Yakima Valley	25	110	964	4,007	2,105	742	795	974	951	284	425	14	11,396
South Idaho	4	5	532	1,579	752	203	185	174	108	20	6	------	3,568
Hood River	------	4	52	738	939	467	608	336	199	101	75	------	3,519
Spokane district	------	3	93	1,221	857	131	126	90	50	31	8	2	2,612
Walla Walla	3	8	93	500	427	98	51	46	12	------	------	------	1,238
West Oregon	2	3	48	291	270	132	43	18	26	5	5	------	843
Medford - Rogue River	------	1	55	222	156	137	97	14	10	2	------	------	694
East Oregon	------	1	30	185	173	57	55	23	3	1	------	------	528
Montana	------	23	108	269	73	8	5	4	5	5	------	------	500
West Washington	1	------	------	6	3	3	7	6	------	2	------	------	28
Total	38	204	2,608	12,791	9,193	2,805	2,849	2,484	2,280	1,227	559	16	37,054

WENATCHEE VALLEY DISTRICT.[1]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Appledale	7	10	4	------	------	------	------	------	21
Brewster	37	160	125	42	16	16	11	9	416
Cashmere	29	310	352	85	174	110	163	195	1,423
Chelan	13	184	188	68	56	43	77	21	650
Dryden	11	106	117	29	55	21	53	92	492
Ellisford	------	3	7	------	1	20	------	------	31
Entiat	42	200	186	54	60	29	41	23	639
Leavenworth	3	25	35	9	4	9	1	------	86
Malaga	6	78	69	21	13	21	27	7	245
Mallott	------	20	------	------	------	2	------	------	22
Monitor	35	210	211	45	35	32	35	40	644
Monse	------	4	1	------	------	------	------	------	5
Ohio Colony Spur	18	41	22	------	------	40	------	------	121
Okanogan	24	102	101	12	3	17	37	21	317
Olds	71	251	234	77	72	59	42	32	838
Omak	13	319	257	20	27	44	150	33	869
Oroville	2	41	19	2	6	2	2	1	75
Palisades	10	------	26	18	1	------	------	------	55
Pateros	36	159	139	38	29	11	7	------	419
Peshastin	13	131	133	35	76	42	22	23	476
Riverside	------	1	8	------	------	------	------	------	9
Starr	------	1	1	2	------	------	------	------	4
Steno	------	7	------	------	------	------	------	------	7
Tonasket	------	37	46	9	9	5	1	------	107
Wagnersburg	4	42	50	8	2	3	9	15	134
Wells	2	17	3	10	1	------	------	------	33
Wenatchee	255	1,295	1,083	239	233	248	237	264	3,914
Winesap	------	6	9	4	4	------	1	------	24
Zena	2	11	10	------	------	------	------	------	23
Total	633	3,773	3,438	827	877	774	916	776	12,103

[1] Totals include following shipments: 3 cars in July, 46 cars in August, and 40 cars in May; also 1 car from Moses Coulee and 3 from Vulcan.

Pacific Northwest car-lot shipments of apples, 1919–20 season, by States, principal districts, and shipping stations—Continued.

YAKIMA VALLEY DISTRICT.[2]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Benton	24	37	8		1	7	3		80
Buena	43	126	60	16	14	22	35	14	347
Byron	1	23	4	2					30
Dalton	4								4
Donald	2	6	7	1					20
Ellensburg		23	7		3				33
Grandview	175	533	263	62	68	72	46	8	1,233
Granger	20	66	20	8	19	1	5	1	141
Hanford	17	39	33	2	2	6	7		109
Kennewick	105	248	158	59	61	31	13		677
Kittitas			5	4					9
Mabton	37		33	11	2				83
Naches	3	61	41	21	19	22	2		169
Outlook	3	19	1						23
Parker	3	12	3						18
Pasco	3	6	8					1	20
Plymouth		6							6
Prosser	51	148	79	31	32	15	2	2	360
Selah	21	196	68	66	43	40	30	10	495
Sunnyside	46	117	48	14	3				244
Thrall	2	19	12	3					36
Toppenish	55	151	79	10	8	5	6		315
Wapato	66	158	71	35	35	38	27	3	481
White Bluffs	29	47	43	1	4	2	8		135
Yakima	183	1,640	865	331	430	575	640	199	5,233
Zillah	71	323	189	65	51	138	127	46	1,092
Total	964	4,007	2,105	742	795	974	951	284	11,396

SOUTHERN IDAHO DISTRICT.[3]

Boise		41	14						55
Buhl	22	45	9	3	5	2			86
Caldwell	63	133	4						200
Council	8	66	28	4	9	5			120
Emmett	17	54	19	3	2	3	4		102
Filer	3	14	18	5					40
Fruitland	115	214	169	91	76	73	29		773
Kimberly	7	33	7		1				48
Kuna		12				5	1		18
Meridian		21	3						24
Nampa	14	182	85	12	13				306
New Plymouth			66	27	27	25	25		170
Parma	60	119	37	9					225
Payette	121	360	168	39	45	51	49	20	862
Twin Falls	83	153	47	9	6	10			308
Weiser	18	119	73	1					211
Wendell		4							4
Wilder	1	3							4
Total	532	1,579	752	203	185	174	108	20	3,568

[2] Totals include following shipments: 25 cars in July, 110 in August, 425 in May, and 14 in June; also 1 car from Thorp and 2 from Marlin.

[3] Totals include following shipments: 4 cars in July, 5 in August, and 6 in May; also 1 car from Montour, 2 from Blackfoot, and 3 each from Houston, Pocatello, and Shoshone.

Pacific Northwest car-lot shipments of apples, 1919–20 season, by States, principal districts, and shipping stations—Continued.

WHITE SALMON AND HOOD RIVER DISTRICT.[4]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Dee, Oreg		4	9	4	13	1			31
Dufur, Oreg		70	40	1					111
Hood River, Oreg	39	236	328	251	191	134	79	87	1,421
Lents (Portland), Oreg			4	2	2				8
Mohr, Oreg			8	1	5	2	6		22
Mosier, Oreg	4	10	65	16	29	32	10	1	167
Odell, Oreg	2	129	142	64	132	30	36	1	538
Parkdale, Oreg	3	28	31	11	46	27	2		149
Summitt, Oreg		2	2	9	3	2	1		19
The Dalles, Oreg		8	13	6	1	1		2	31
Troutcreek, Oreg		5	7	2					14
Van Horn, Oreg		79	128	44	166	99	59	9	584
Woodworth, Oreg	1	2	3	3		2			11
Goldendale, Wash		9	12						21
Underwood, Wash	1	92	74	17	12	2	4		202
White Salmon, Wash		64	73	36	8	3	2	1	187
Total	52	738	939	467	608	336	199	101	3,519

SPOKANE DISTRICT.[5]

Addy		3	6						9
Bonners Ferry, Idaho		8	3						11
Colville		4	2						6
Coulee City	5	7	9			8			29
Creston	5	34	2						41
Davenport	1	26	12	4					43
Davies Spur, Wash			10						10
Dean, Wash		5							5
Deer Park	7	20	11	1					39
Denison			11						11
Dishman	16	143	26	9	22	6	2		224
Ephrata		8	12						20
Fairfield, Wash		35	27		2				64
Farmington, Wash		4	7			1			12
Four Lakes		30	19	7	12	7			75
Garfield		3	4						7
Greenacres		29	13		1		1		44
Hillyard	7	55	3	11	2	1	2		81
Hooper		8							8
Marcus	1	16	3			1			21
Meyers Falls	5	89	40	8	14		1		157
Millwood		9	1						10
Neppel	13	78	44	2					137
Northport		5	3			1	1		10
Opportunity			141						141
Otis Orchards	1	99	69	6	21	5			201
Pullman			4	5					9
Quincy		11	4						15
Soap Lake		21	23	5	1				50
Spokane	2	154	119	25	29	32	38	31	441
Spokane Bridge		3	10						13
Sprague			22						22
Trinidad	20	48	11		2				83
Vera			13						13
Waverly, Wash		18	10	1	3	1			33
Wilson Creek, Wash		55	36	20	10	8			129
Coeur d'Alene, Idaho		48	28						76
Hauser, Idaho		4	8						12
Lewiston, Idaho	9	110	71	25	7	19	5		246
McGuires, Idaho		7							7
Moscow, Idaho		10	1						11
Post Falls, Idaho	1	2	9	1					13
Total	93	1,221	857	131	126	90	50	31	2,612

[4] Totals include the following shipments: 4 cars in August and 75 cars in May; also 1 car from Holstein, Oreg., and 2 from Maryhill, Wash.

[5] Totals include following shipments: 3 cars in August, 8 cars in May, and 2 cars in June; also 1 car each from Albion, Wash., Colfax, Loon Lake, Usk, Alan, Laclede, and Porthill, Idaho; 2 cars each from Cheweleh, Dart, Kiesling, Genessee, and Rose, Idaho; and 3 cars each from Galena, Idaho, and Valleyford, Wash.

Pacific Northwest car-lot shipments of apples, 1919–20 season, by States, principal districts, and shipping stations—Continued.

WALLA WALLA-MILTON-FREEWATER DISTRICT.[6]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Ayer Junction, Wash			5						5
Dayton, Wash	11	82	53	9	12	6	8		181
Dixie, Wash		3	3						6
Prescott, Oreg			2						4
Touchet, Wash	11	30	36	6	3				86
Waitsburg, Wash	6	67	61	7	12	11	3		167
Walla Walla, Wash	40	201	142	33	9	9	1		443
Wallula, Wash	12	31	26	2					72
Milton-Freewater, Oreg	13	83	99	41	15	20			271
Total	93	500	427	98	51	46	12		1,238

WESTERN OREGON DISTRICT.[7]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Albany	1	3	8						12
Brogan	7	29	15						51
Brownsville			4						4
Corvallis	3	10	4	1	2				20
Creswell	1	19	20	2		5			47
Dallas		8	10	1					19
Drain		2	2						4
Eugene	5	16	18	1					41
Halsey		2	1	1					5
Hillsboro	1	3							4
Hubbard	2	6	2	1	1				12
Junction City	4	5		1	1	1			14
Lafayette		8	8	9					25
Lebanon				3	2				5
McMinnville	3	14	11	7	2				37
Monmouth	1	3							4
Monroe	1	11	7	6					25
Newberg	1	31	27	5	4				68
Portland		2	2	2	4	6	26	5	52
Riddle		6	12	2					20
Roseburg	5	32	63	70	6				176
Salem	5	26	14	4					49
Sheridan	2	13	17	5	14	5			56
Silverton		4	2						6
Tigard	2		3						6
Tualatin		4	1						5
Wilsonville		5	3	5	3	1			17
Yoncalla		8							8
Total	48	291	270	132	43	18	26	5	843

MONTANA DISTRICT.[8]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Darby	10	26	7	1					46
DeSmet		2	2	1		1			6
East Bridger	1	4							5
Fromberg	8	2							13
Hamilton	49	104	35	5	1	1	5	2	208
Lo Lo		2	1		1	1			5
Silesia	4	4							8
Somers		3	4						7
Stevensville	11	41	8					1	62
Victor	1	20	6		1	1			31
Woodside	21	55	9		2				94
Total	108	269	73	8	5	4	5	5	500

[6] Totals include following shipments: 3 cars in July and 8 in August; also 3 cars from Attalia, Wash.

[7] Totals include following shipments: 2 cars in July, 3 cars in August, and 5 cars in May; also 1 car each from Amity, Cottage Grove, Deer Island, Garden Home, Gaston, Gray, Mount Angel, Waconda, and Willamina; 2 cars each from Coburg, Fairview, Fall City, Forest Grove, Monitor, Myrtle Point, Robinson, Sherwood, and Springfield; and 3 cars each from Chemawa, Clackamas, Crabtree, Dayton, Fayetteville, West Scio, Wigrich, and Woodburn.

[8] Totals include following shipments: 23 cars in August; also 1 car each from Billings, Flaxville, Helena, Livingston, and Polson; 2 cars each from Park City and Ravalli; and 3 cars each from Edgar and Missoula.

Pacific Northwest car-lot shipments of apples, 1919–20 season, by States, principal districts, and shipping stations—Continued.

WESTERN WASHINGTON.[9]

Stations.	September.	October.	November.	December.	January.	February.	March.	April.	Total.
Seattle		3			7	6			16
Tacoma			2					2	4
Total		6	3	3	7	6		2	28

ROGUE RIVER, OREG., DISTRICT.[10]

Ashland	1	17	13	3	2	1			37
Central Point	2	11	10	1					24
Gold Hill	3	12	10	3					28
Grants Pass	13	35	27	19				1	96
Medford	28	133	88	99	95	13	10	1	467
Rogue River	7	11	6	6					30
Talent	1	2	2	5					10
Total	55	222	156	137	97	14	10	2	694

EASTERN OREGON.[11]

Beaverton		1	4		1				7
Cairo		7							7
Cove		11	6	1	3	7			28
Elgin		1	13	7	9				30
Hermiston	4	17	16	4					41
Huntington		2				1	1	1	5
Imbler	2	11	44	11	35	15			118
Irrigon		1	2	1					4
La Grande		24	29	10	7		2		72
Mallett		2							2
Nyssa	13	29	6	9					57
Ontario	1	15	17	6					39
Stanfield	4	22	17						43
Union		18	10	1					29
Vale	6	23	9	6					44
Total	30	185	173	57	55	23	3	1	528

[9] Totals include following shipments: 1 car in July; also 1 car each from Everett, Port Angeles, and Woodland; 2 cars from Kelso; and 3 cars from Vancouver.
[10] Totals include following shipments: 1 car in August; also 2 cars from Merlin.
[11] Totals include following shipments: 1 car in August; also 1 car each from Jamieson and North Powder.

EXHIBIT No. 3.

The car-lot shipment figures in the following tabulation were taken from telegraphic reports from division superintendents of common carriers. These figures are given here to show by comparison the relative importance of the main apple-producing sections of the United States.

The Central Appalachian section consists mainly of the important apple-producing portions of Virginia and West Virginia and a few contiguous counties of Maryland and Pennsylvania. Most of this section lies within the watershed of the Potomac and its tributaries.

Shipments of less than car lots and apples brought into large terminal markets from near-by producing sections are not included.

	Washington.	Oregon.	Idaho.	Montana.	Total Pacific Northwest.	New York.	Central Appalachian.	Total United States.
1916–17..	14,426	3,041	182	145	17,693	10,206	11,748	57,821
1917–18..	15,837	3,448	3,528	171	22,984	5,867	7,212	58,534
1918–19..	16,232	2,246	536	262	19,276	22,900	9,625	69,552
1919–20..	24,476	4,768	3,574	452	33,270	10,234	11,392	82,514

Exhibit No. 4.

GRADING RULES AND REGULATIONS FOR APPLES.

[As adopted by Washington State Department of Agriculture.]

DEFINITION OF TERMS.

Tolerance.—In order to provide for the variations incident to commercial grading and handling, a "tolerance" of 5 per cent for a total of all defects from the standard will be permitted in all grades, and shall be computed by counting, weighing, or measuring the specimens judged to be below the standard of the grade.

Uniform in size.—The term "uniform in size" shall be construed to mean that apples in any one package shall not vary more than one-half inch in their greatest transverse diameter.

Packing.—The term "properly packed" shall refer to the arrangement of apples in each package; apples to be properly packed shall be arranged in the container according to the approved and recognized methods, and all packages shall be tightly filled, but the contents shall not show excessive or "unnecessary bruising" as a result of the pressure exerted in inclosing an overfilled package.

APPLE-GRADING RULES.

(Season 1920.)

Extra Fancy.—Extra Fancy apples are defined as sound, mature, clean, hand-picked, well-formed apples only, free from all insect pests, diseases, blemishes, bruises and holes, spray burns, limb rub, visible water core, skin punctures or skin broken at stem, but slight russeting within the basin of the stem shall be permitted.

Fancy Grade.—Fancy apples are defined as apples complying with the standard of Extra Fancy Grade, except that slight leaf rubs, scratches, or russeting shall be permitted up to a total of 10 per cent of the surface, and provided that scab spots not larger than one-quarter inch in diameter in the aggregate shall be permitted in this grade.

"*C*" *Grade.*—"C" Grade apples shall consist of sound, mature, hand-picked apples which are practically free from infection, bruising, or broken skin, and which are not badly misshapen, provided that two healed worm stings, slight sun scald, and scab up to a total of one-half inch in diameter shall be permitted in this grade.

Combination Grade.—When Extra Fancy and Fancy apples are packed together, the boxes must be marked "Combination Extra

Fancy and Fancy." When Fancy and "C" Grade apples are packed together, the box must be marked "Combination Fancy and 'C' Grades." Combination grades must contain at least 25 per cent of apples which are of such grade as would be permitted in the higher grades. None of the higher-grade apples shall be sorted out of any lot and the remainder packed as combination grade.

Orchard Run.—When Extra Fancy, Fancy, and "C" Grade apples are packed together, the boxes must be marked "Orchard Run," but Orchard Run apples must not contain any fruit that will not meet the requirements of "C" Grade. It shall be unlawful to remove any of the higher-grade apples from any lot and then pack the remainder as "Orchard Run."

Unclassified.—All firm apples which are practically free from infection, but which do not conform to the foregoing specifications of grade, or, if conforming, are not branded in accordance therewith, shall be classed as "Unclassified" and so branded, provided that no restriction shall be placed on the number of worm stings admitted to this class. Open wormholes will not be permitted. This grade must be plainly marked with the word "Unclassified."

COLOR REQUIREMENTS.

Apples shall be admitted to the First and Second grades subject to the following color specifications. The percentage stated refers to the area of the surface which must be covered with a good shade of red.

	Extra Fancy.	Fancy.		Extra Fancy.	Fancy.
SOLID RED VARIETIES.	*Per ct.*	*Per ct.*	STRIPED OR PARTIAL RED VARIETIES—continued.	*Per ct.*	*Per ct.*
Aiken Red	75	25	Willow Twig	50	15
Arkansas Black	75	25	Wagener	50	15
Baldwin	75	25	Wealthy	50	15
Black Ben Davis	75	25	York Imperial	25	10
Detroit Red	75	25	Alexander	25	10
Gano	75	25	Chenango	25	10
King David	75	25	Gravenstein	25	10
Red June	75	25	Jeffries	25	10
Spitzenburg Esopus	75	25	King	25	10
Spitzenburg Kaign	75	25	Oldenburg	25	10
Vanderpool	75	25	Shiawassee	25	10
Winesap	75	25	Twenty Ounce		
Jonathan	66⅔	25			
McIntosh Red	66⅔	25	RED CHEEKED OR BLUSHED VARIETIES.		
STRIPED OR PARTIAL RED VARIETIES.			(Extra Fancy, perceptibly blushed cheek; Fancy, tinge of color.)		
Delicious	66⅔	25			
Stayman Winesap	66⅔	25		.....	.....
Black Twig	50	25	Hydes King	.....	.....
Ben Davis	50	15	Maiden Blush	.....	.....
Bonum	50	15	Red Cheek Pippin	.....	.....
Fameuse	50	15	Winter Banana		
Geniton	50	15	GREEN AND YELLOW VARIETIES.		
Hubbardston	50	15			
Limbertwig	50	15	(Extra Fancy, characteristic color; Fancy, characteristic color.)		
Missouri Pippin	50	15			
Northern Spy	50	15			
Ontario	50	15	Grimes Golden	.....	.....
Red Astrachan	50	15	Yellow Newtown	.....	.....
Rainier	50	15	White Winter Pearmain	.....	.....
Rome Beauty [1]	50	15	Cox's Orange Pippin	.....	.....
Salome	50	15	Ortley	.....	.....
Stark	50	15	Yellow Bellefleur	.....	.....
Sutton	50	15	Rhode Island Greening	.....	.....

[1] No color requirement on Fancy Rome Beauty 96 and larger.

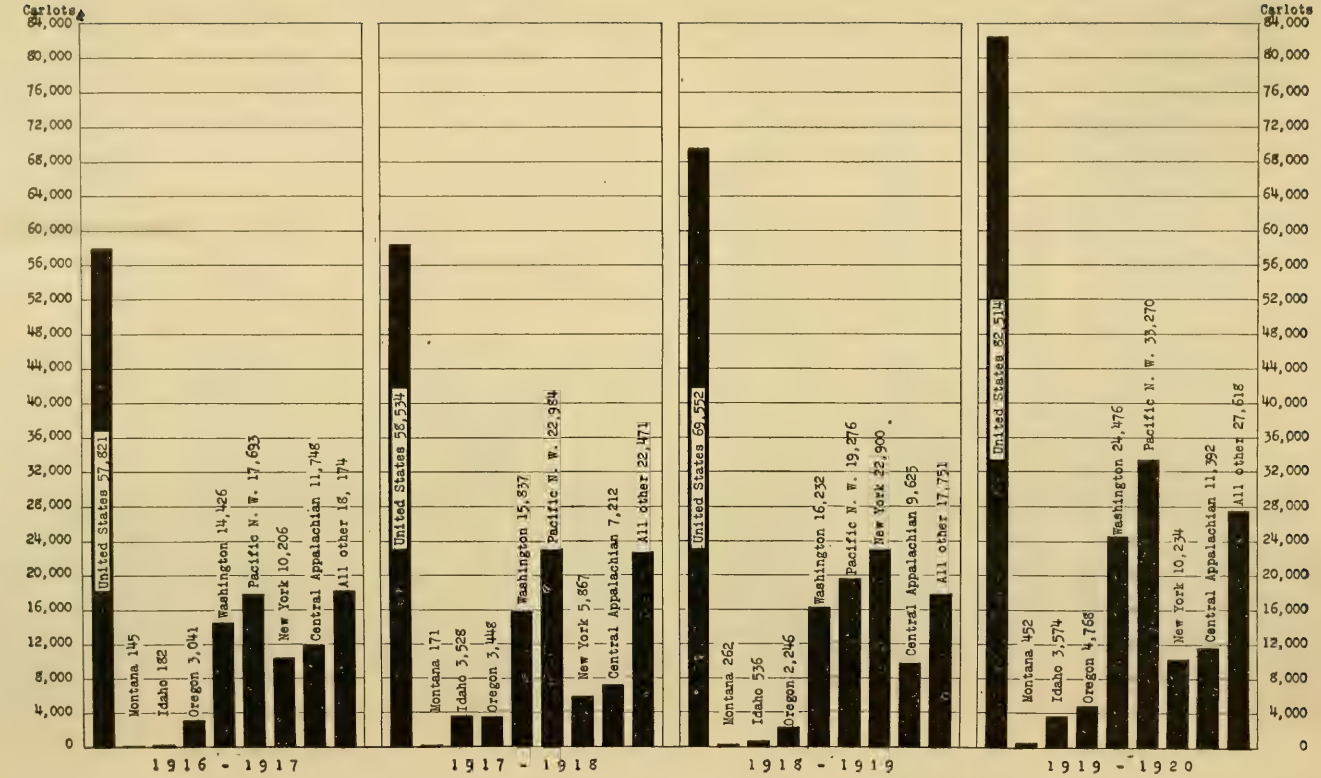


EXHIBIT No. 6.—Total carlot shipments of apples for the United States and the three principal apple-producing sections of the country. 1916–1917 to 1919–1920.

EXHIBIT No 5.

The following table shows the cold-storage holdings in the United States of boxed and barreled apples on December 1, 1916, 1917, 1918, and 1919, segregated geographically. These figures were compiled from monthly reports submitted to the Bureau of Markets by all the principal cold storages and represent the greater part of stocks held in cold storage on December 1 of each of the years mentioned:

	Year.	Boxes reduced to car lots.	Barrels reduced to car lots.	Total car lots.
Connecticut, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Pennsylvania, New Jersey, New York, Delaware, Maryland, District of Columbia, Virginia, West Virginia.	1916	1,009	11,401	12,410
	1917	936	10,496	11,432
	1918	1,128	13,688	14,816
	1919	1,848	12,950	14,798
Florida, Georgia, North Carolina, Alabama, South Carolina, Kentucky, Louisiana, Tennessee, Mississippi.	1916	146	1,170	1,316
	1917	219	1,454	1,673
	1918	262	1,121	1,383
	1919	332	981	1,313
Illinois, Indiana, Michigan, Ohio, Iowa, Wisconsin, Kansas, Minnesota, Nebraska, Missouri, North Dakota, South Dakota.	1916	1,786	8,502	10,288
	1917	1,785	8,822	10,607
	1918	1,815	5,562	7,377
	1919	3,337	6,323	9,660
Oklahoma, Texas, New Mexico, Arkansas, Colorado	1916	474	205	679
	1917	599	386	985
	1918	644	122	766
	1919	801	521	1,322
Arizona, California, Nevada, Utah	1916	1,376	.....	1,376
	1917	1,574	.....	1,574
	1918	1,663	.....	1,663
	1919	1,897	.....	1,897
Idaho, Montana, Wyoming, Oregon Washington	1916	2,150	.....	2,150
	1917	1,873	.....	1,873
	1918	1,509	.....	1,509
	1919	2,104	.....	2,104
United States	1916	6,941	21,278	28,219
	1917	6,986	21,158	28,144
	1918	7,021	20,493	27,514
	1919	10,319	20,775	31,094

EXHIBIT No. 6.

(See preceding chart.)

The preceding chart shows the season's car-lot shipments for the United States, Pacific Northwest, New York State, and the Central Appalachian district for the crop years 1916 to 1919. The figures used in this chart were telegraphed daily by the division superintendents of the railroads on which shipments of apples originated. It will be noted that these daily reports aggregate 33,270 cars for the Pacific Northwest for the 1919–20 season, while the reports by shipping stations, as shown in Exhibit No. 2, aggregate 37,054. The larger total is probably more accurate, but the former is used in this chart to bring about more uniform comparison between figures for the Pacific Northwest and the other sections mentioned.

Exhibit No. 7.

(See folding chart.)

The figures used in making this chart showing the rate of movement for each of the last four years, indicating the influence of shipments from the Pacific Northwest on the total movement for the United States, were taken from daily telegraphic reports of shipments from division superintendents from all roads in the country on which car-lot shipments of apples originated.

In making this chart semimonthly periods were used. The rate of movement line and the line over the 16th and 1st of each month indicate the number of cars which moved during that period.

Exhibit No. 8.

(See following maps.)

The dots on these maps show the points to which apples were destined from the Pacific Northwest, New York State, and the central Appalachian section, respectively. These show primary destinations only, as diversion information was incomplete and in most cases not available.

The map representing destinations from the Pacific Northwest covers a period of five years. The destinations shown for New York State and the Central Appalachian section cover a period of two years.

Exhibit No. 9.

In the following tabulation are shown the primary destination of about 30,000 cars shipped from the Pacific Northwest during the 1919–20 season.

This list represents primary distribution only. Complete diversion information would probably show a much larger list of destinations. The tabulation showing shipments originally destined to 2,567 cities and towns indicates the widespread distribution of northwestern apples.

UNITED STATES.

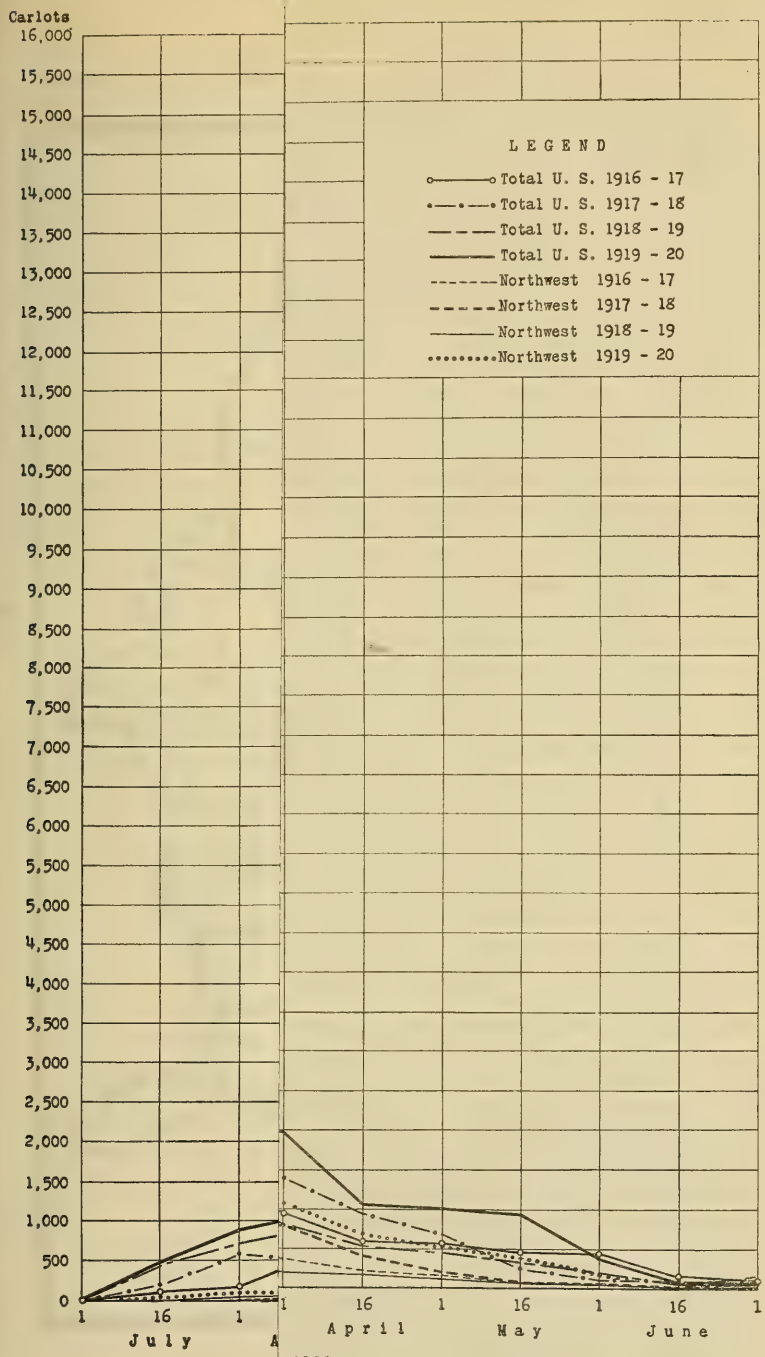
Alabama:[1]	
Birmingham	55
Mobile	29
Montgomery	28
Arizona:[2]	
Bisbee	14
Douglas	6
Phoenix	13
Tucson	4
Arkansas:[3]	
Fort Smith	10
Jonesboro	7
Little Rock	25
Texarkana	22
California:[4]	
Fresno	11
Los Angeles	139
Oakland	27

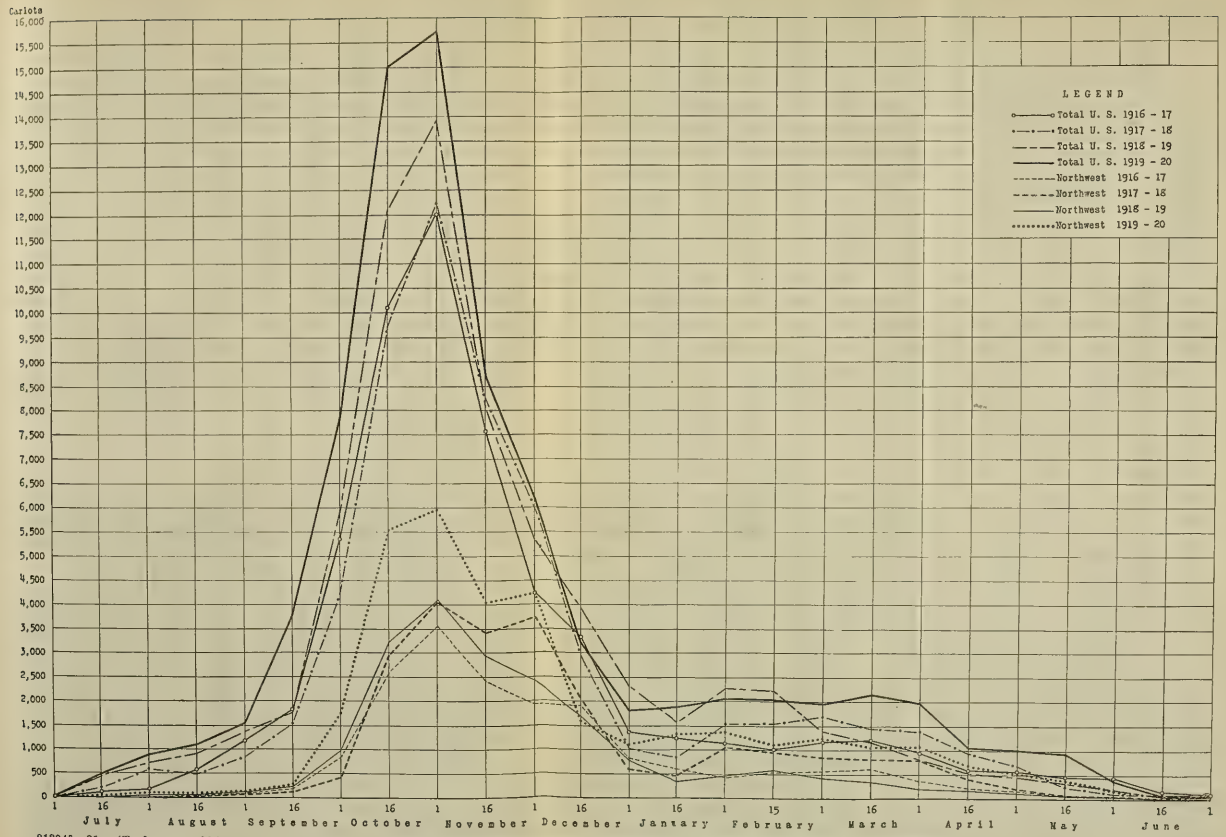
[1] The following additional consignments were made to Alabama points: 1 car each to Gallion, Haynes, Huntsville, Pierce, Pineville, and Selma; 2 cars to Paul; 3 cars to Dotham.

[2] The following additional consignments were made to Arizona points: 1 car each to Del Rio, Flagstaff, Gadsden, and Yuma.

[3] The following additional consignments were made to Arkansas points: 1 car each to Blytheville, Centerville, Elnora, Faith, Foreman, Franklin, Hope, Hot Springs, Pine Bluff, Rhyme, and Turn Bull; 2 each to Camden, McNeil, and Warren.

[4] The following additional consignments were made to California points: 1 car each to Bakersfield, Berkeley, Burns, Chico, Escondido, Lodi, Long Beach, Princeton, Redding, San Bernardino, San Luis, and Santa Monica; 2 each to Hinkley, Modesto, Pasadena, Santa Barbara, and Seaside; 3 cars to Colton.


Carlots
16,000
15,500
15,000
14,500
14,000
13,500
13,000
12,500
12,000
11,500
11,000
10,500
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
LEGEND
Total U. S. 1916 - 17
Total U. S. 1917 - 18
Total U. S. 1918 - 19
Total U. S. 1919 - 20
Northwest 1916 - 17
Northwest 1917 - 18
Northwest 1918 - 19
Northwest 1919 - 20
1
16
1
16
1
16
1
July
April
May
June



21394°—21. (To face page 20.)

EXHIBIT No. 7.—Rate of carlot movement of apples, United States and Pacific Northwest 1916–1917 to 1919–1920.

Exhibit No. 8.—Primary distribution of carlot shipments from the Pacific Northwest.

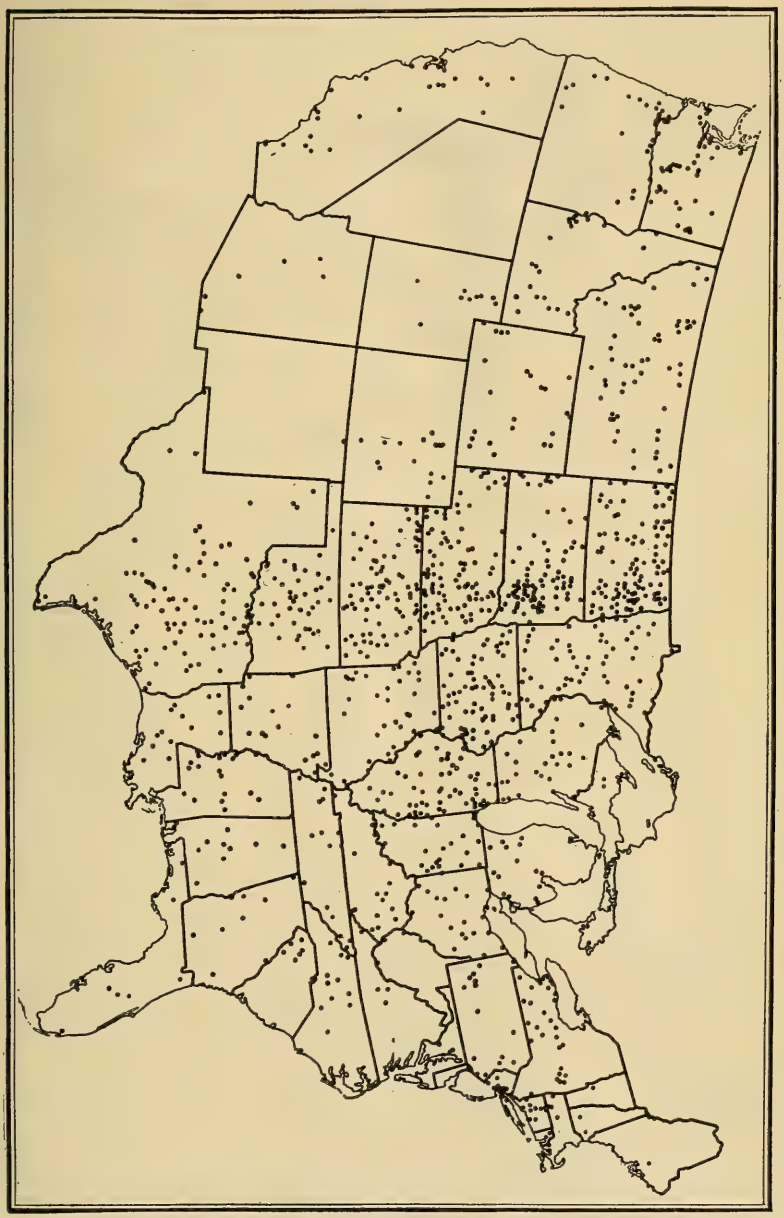


EXHIBIT No. 8 (Continued).—Primary distribution of carlot shipments from New York State.

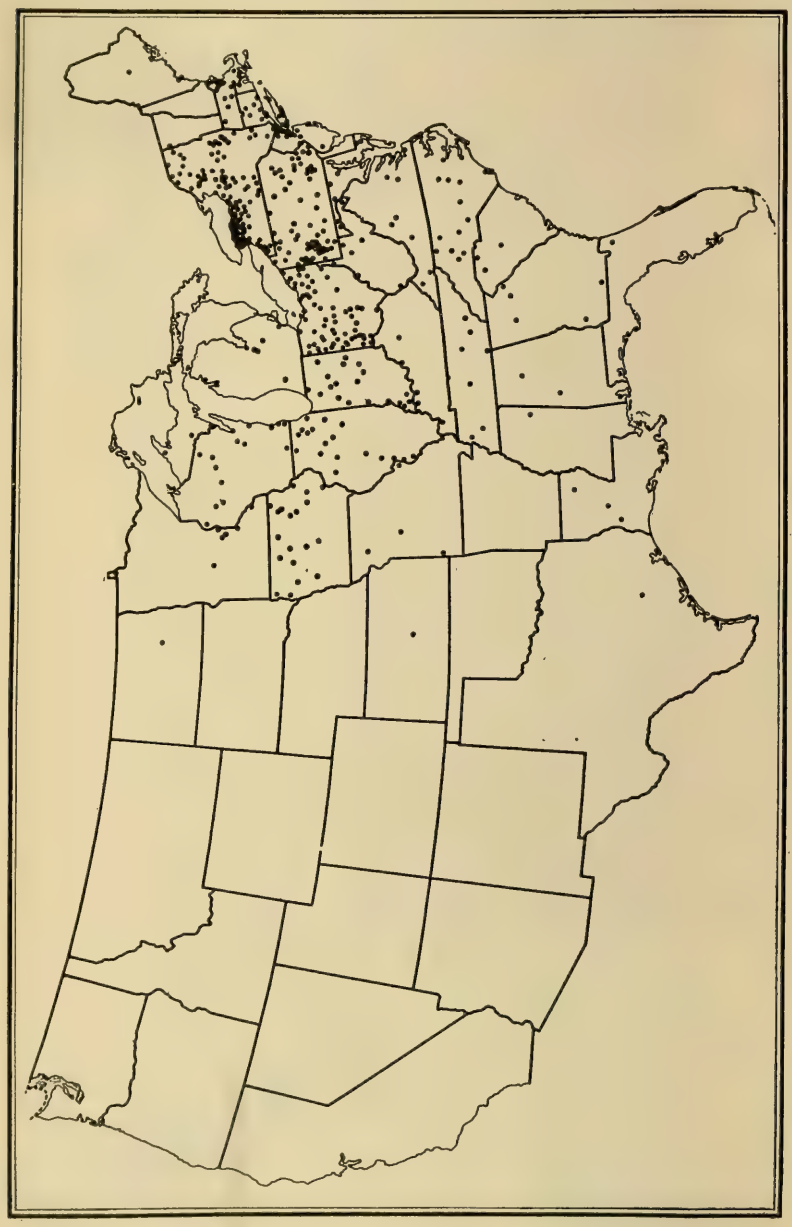
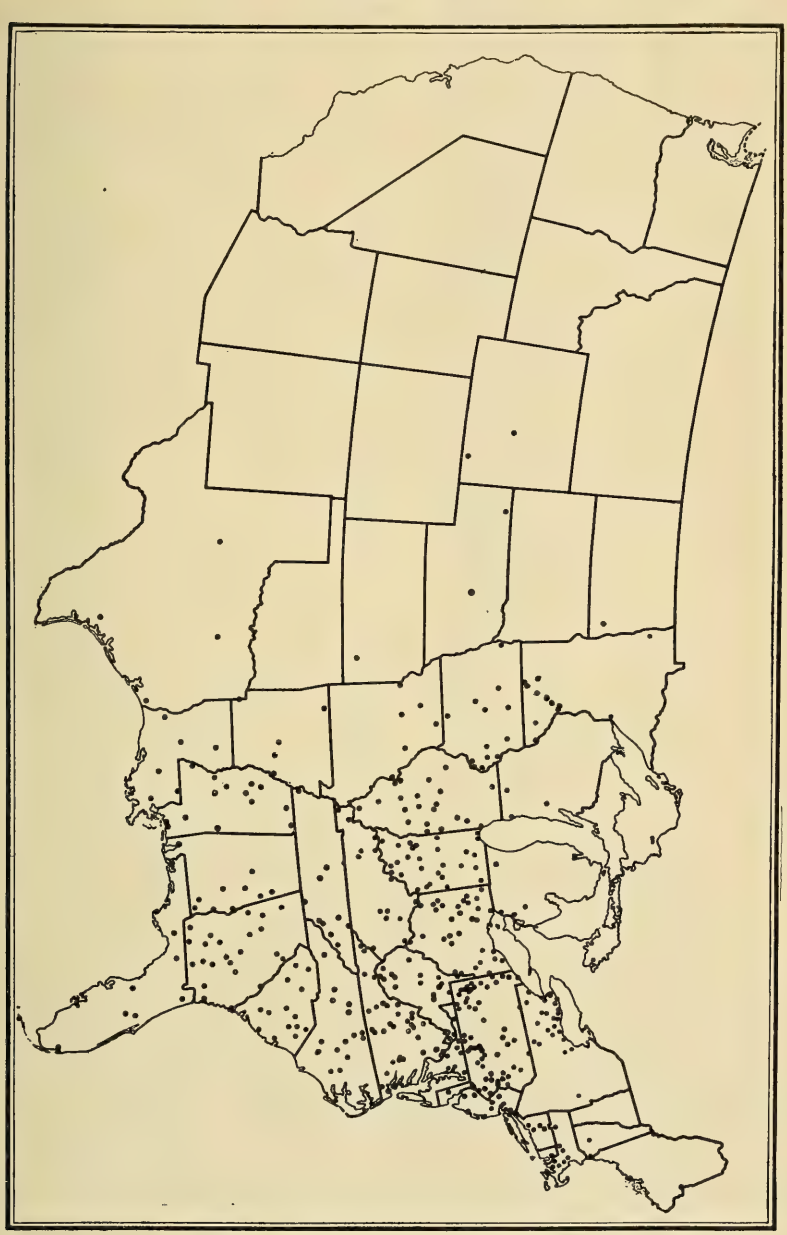


EXHIBIT No. 8 (Continued).—Primary distribution of carlot shipments from the Central Appalachian district.



California—Continued.	
Pomona	5
Portola	13
Sacramento	25
San Diego	16
San Francisco	222
San Jose	13
Stockton	13
Watsonville	30
Colorado:[5]	
Colorado Springs	4
Denver	1,292
Pueblo	13
Trinidad	26
Connecticut:[6]	
Bridgeport	17
Hartford	28
New Haven	15
Waterbury	4
Delaware.[7]	
District of Columbia:	
Washington	82
Florida:[8]	
Jacksonville	38
Key West	9
Pensacola	14
Tampa	27
Georgia:[9]	
Atlanta	90
Augusta	21
Columbus	4
Macon	7
Idaho:[10]	
Boise	5
Loraine	6
Montpelier	4
Moscow	11
Nampa	9
New Plymouth	13
Payette	163
Pocatello	75
St. Anthony	5
Illinois:[11]	
Aurora	5
Bloomington	24
Bridgeport	11
Cairo	15
Chicago	4,254
Decatur	9
Joliet	8
Monmouth	4
Neoga	16
Oak Park	13
Oliver	4
Ottawa	10
Peoria	24
Rockford	11
Springfield	12
Streator	4
Valley	23
Indiana:[12]	
Evansville	16
Fort Wayne	9
Indianapolis	169
Miller	4
Milton	4
South Bend	4
Terre Haute	4
Vincennes	88
Iowa:[13]	
Burlington	15
Cedar Rapids	28
Clinton	21
Correctionville	4
Council Bluffs	10
Davenport	18
Des Moines	90
Dubuque	10
Fort Dodge	20
Fruitland	12
Harvey	9
Malvern	22
Marshalltown	32
Mason City	10

[5] The following additional consignments were made to Colorado points: 1 car each to Agate, Akron, Boulder, Cheraw, Greeley, La Salle, Otis, and Simon; 2 each to Eaton, Rocky Ford, Sterling, and Wray.

[6] The following additional consignments were made to Connecticut points: 1 car each to Danbury and New Britain; 2 each to Meriden, New London, and Norwich.

[7] The following consignment was made to Delaware: 1 car to Wilmington.

[8] The following additional consignments were made to Florida points: 1 car each to Baynard, Blackman, Carolina, Leonard, and Torrey; 2 cars to Miami.

[9] The following additional consignments were made to Georgia points: 1 car each to Kramer and Mount Pleasant; 2 each to Harris, New England, and Valdosta.

[10] The following additional consignments were made to Idaho points: 1 car each to American Falls, Buckingham, Burke, Glenns Ferry, Idaho Grove, Malad City, Minidoka, Moss, Rexburg, and Wallace; 2 each to Blackfoot, Burley, Idaho Falls, Kooskia, Meridian, and Rupert; 3 cars to Goodrich.

[11] The following additional consignments were made to Illinois points: 1 car each to Amboy, Arthur, Avon, Benton, Blandinsville, Cissna Park, De Kalb, Duquoin, Franklin Grove, Freeport, Galesburg, Grayville, Jefferson Park, Kansas, Martinsville, Mattoon, Northfield, Oneida, Orion, Pontiac, Princeville, Proctor, Quincy, Richardson, Rock Island, Roscoe, Simons, Velma, Warrington, Waukegan, and Worden; 2 each to Ashley, Champaign, Danville, Kewanee, Litchfield, Murphysboro, Normal, Oregon, Paxton, and Wheaton; 3 each to Centralia and New Salem.

[12] The following additional consignments were made to Indiana points: 1 car each to Anderson, Gessie, Knox, Kokomo, Michigan City, Muncie, Steubenville, and Whiting; 2 each to Rushville, Union City, and Warsaw; 3 each to Elwood, Evanston, Logansport, Newcastle and Williamsport.

[13] The following additional consignments were made to Iowa points: 1 car each to Ames, Atlantic, Bagley, Belmond, Bernard, Carroll, Clarion, Cresco, Croton, Decorah, Drum, Dumont, Eagle Grove, Fort Atkinson, Garner, Herrold, Jefferson, Kalona, Lacona, Manchester, Manly, Melrose, Miles City, Paullina, Reinbeck, Rock Valley, Sac City, Shenandoah, Sumner, Sutherland, Tama, Trask, Tripoli, Valvern, Van Wert, and Williams; 2 each to Algona, Ashton, Chariton, Lisbon, Macedonia, Rock Rapids, Tiffin, West Liberty, and Westside; 3 each to Beaver, Creston, Dixon, Grinnell, Hampton, Kingsley, Raymond, Sheldon, and Spencer.

Iowa—Continued.	
Ontario	8
Ottumwa	13
Sioux City	129
Waterloo	23
Kansas: [14]	
Arkansas City	4
Bird City	4
Coffeyville	6
Concordia	4
Ellsworth	4
Geneseo	4
Hays	9
Hutchinson	7
Independence	6
Marion	6
Melvern	17
Newton	9
Parsons	10
Topeka	33
Wichita	51
Winfield	21
Yates Center	6
Kentucky: [15]	
Lexington	20
Louisville	82
Louisiana: [16]	
Alexandria	18
Baton Rouge	4
Mansfield	4
Monroe	5
Maine: [17]	
Bangor	7
Portland	169
Maryland: [18]	
Baltimore	260
Massachusetts: [19]	
Boston	247
Holyoke	6
New Bedford	9
Springfield	22
Worcester	8
Michigan: [20]	
Champion	6
Detroit	194
Grand Rapids	9
Greenwood	7
Saginaw	4
Minnesota: [21]	
Albert Lea	13
Butler	4
Crookston	16
Duluth	176
Effie	5
Fairmont	5
Le Roy	321
Minneapolis	4,058
Minnesota Transfer	60
Mitchell	12
Moorhead	6
Pipestone	5
St. Cloud	7
St. Paul	329
Thief River Falls	18
Tracy	10
Virginia	7
Wadena	4
Willmar	5
Mississippi: [22]	
Jackson	19
Meridian	53
Vicksburg	6

[14] The following additional consignments were made to Kansas points: 1 car each to Abilene, Almena, Atchison, Bancroft, Beardsley, Bedford, Belmont, Beloit, Benedict, Bentley, Bubbock, Bucklin, Carlton, Chanute, Clyde, Colby, Courtland, Eldorado, Ellinwood, Englevale, Garfield, Grinnell, Hamburg, Haven, Helca, Herndon, Holton, Iola, Jetmore, Little River, Lorraine, Lucas, Ludell, Lyons, McPherson, Manchester, Manhattan, Marysville, Meade, Norcatur, Ogdensburg, Rushcenter, St. John, Summerfield, Traer, Wakeeney, Washington, Wellington, Wheeler, and Wilmore; 2 each to Baxter, Bremen, Eureka, Fort Scott, Garden City, Jennings, Junction City, Kellogg, Mankato, Mitchell, Norton, and Oberlin; 3 each to Dodge City, Emporia, Goodland, Great Bend, Harper, Ottawa, and Salina.

[15] The following additional consignments were made to Kentucky points: 1 car each to Bowling Green, Henderson, Johnsonville, Montague, Paducah, Sharon Springs, Silver Creek, Soldier, and Wolf Pit; 2 each to Owensboro and Pineville; 3 each to Boone, Frankfort, Fremont, Marshall, and Middlesboro.

[16] The following additional consignments were made to Louisiana points: 1 car each to Crowley, Fullerton, Gibsland, Hazel, Lewisville, Maurice, and Morgan City; 2 each to Fayette and Lucas; 3 cars to Shreveport.

[17] The following additional consignments were made to Maine points: 1 car each to Auburn and Merden.

[18] The following additional consignment was made to Maryland: 2 cars to Locust Point.

[19] The following additional consignments were made to Massachusetts points: 1 car each to Fall River, Pittsfield, and Watuppa.

[20] The following additional consignments were made to Michigan points: 1 car each to Croswell, Harnsville, Lake Linden, Lansing, Lowell, Morenci, Roseburg, Sault Ste. Marie, Sturgis, Trimountain, and Wyandotte; 2 each to Adrian, Battle Creek, Bay City, Hancock, and Wellsford; 3 each to Kalamazoo and Menominee.

[21] The following additional consignments were made to Minnesota points: 1 car each to Aitkin, Battle Lake, Bovey, Breckinridge, Clara City, Clearbrook, Collegeville, Dover, Eden Valley, Elk River, Faribault, Fertile, Harlis, Hendrum, International Falls, Kasson, Kenneth, Marshall, Minneota, Montevideo, Motley, Nashua, Redwood, Richville, Robbinsdale, Sauk Rapids, Washington, Wayzata, and Winton; 2 each to Argyle, Bemidji, Brainerd, Fergus Falls, Langdon, Lismore, Mahnomen, Proctor, Red Wing, and Worthington; 3 each to Chisholm, Ortonville, and Winona.

[22] The following additional consignments were made to Mississippi points: 1 car each to Brookhaven, Fernwood, Foster, Hampton, Hanford, Hattiesburg, Ingomar, Lockhart, McComb, Maben, Malvina, Natchez, Rankin, Richey, and Union; 2 cars to Prairie.

Missouri:[23]	
Carthage	4
Columbia	34
Hannibal	41
Jefferson City	8
Joplin	14
Kansas City	583
St. Joseph	47
St. Louis	306
Montana:[24]	
Anaconda	12
Billings	143
Bozeman	13
Butte	188
Chinook	7
Cut Bank	56
Deer Lodge	6
Farrell	16
Forsyth	4
Glasgow	5
Glendive	4
Great Falls	69
Harlowton	6
Havre	26
Helena	32
Howard	4
Laurel	107
Lewistown	19
Livingston	6
Malta	4
Manchester	5
Miles City	26
Missoula	46
Red Lodge	7
Roundup	14
Shelby	5
Stanford	6
Terry	5
Whitefish	70
Wolf Point	4
Nebraska:[25]	
Alliance	8
Beatrice	7
Crawford	8
Nebraska—Continued.	
Grand Island	477
Harvard	4
Hastings	12
Holdrege	4
Kearney	13
Lincoln	157
Norfolk	15
North Platte	450
Omaha	700
Scottsbluff	10
New Hampshire.[26]	
New Jersey:[27]	
Jersey City	52
Newark	10
Passaic	5
Phillipsburg	6
Trenton	4
New Mexico.[28]	
New York:[29]	
Albany	13
Auburn	11
Ballston Spa	4
Barker	15
Binghamton	4
Brooklyn	5
Buffalo	47
Burt	25
Cornell	5
Dover Plains	15
Elmira	148
Geneva	21
Hilton	37
Hornell	37
Jamestown	32
Lockport	70
Medina	13
New York City	2,401
Niagara Falls	7
Port Richmond	5
Rochester	22
Schenectady	7
Suspension Bridge	98

[23] The following additional consignments were made to Missouri points: 1 car each to Belle, Charles, Clarksdale, Desloge, Fenwick, Flint, Glenwood, Holmes, Louisiana, McDonald, Malden, Matson, Minden, Moberly, Napoleon, Nevada, Plattsburg, Schuyler, Sedalia, Sikeston, Wheeling, and Wright City; 2 cars to Beaver; 3 cars each to Mexico, Springfield, and Winston.

[24] The following additional consignments were made to Montana points: 1 car each to Armstead, Basin, Browning, Chappell, Delphia, Dillon, Garrison, Grassrange, Hingham, Ismay, Judith Gap, Kintyre, Libby, Plentywood, Poplar, Stockett, Valier, Warmsprings, Wennett, and Windham; 2 each to Bigtimber, Conrad, Custer, Eveleth, Medicine Lake, Redstone, Rexford, and Virden; 3 cars each to Big Sandy and Finch.

[25] The following additional consignments were made to Nebraska points: 1 car each to Albion, Ashton, Beaver Crossing, Belgrade, Benkelman, Vereville, Bigsprings, Gladen, Bloomfield, Broken Arrow, Bushnell, Central City, Chadron, Chappell, Cobb, Columbus, Cortland, Cowles, Creighton, Crookston, Curtis, Dannebrog, Deshler, Dorchester, Elsie, Elyria, Fairfield, Fullerton, Germantown, Grafton, Grant, Haigler, Havelock, Hazard, Hebron, Hemingford, Holstein, Hooper, Imperial, Inavale, Lewellen, Long Pine, Loretto, Madison, McCook, Merna, Minden, Moorefield, Newman Grove, Ogallala, Ong, Osmond, Scribner, Shickley, Sterling, Upland, Valley, Venango, Wakefield, Wisner, and York; 2 each to Broken Bow, Cozad, Crete, Culbertson, David City, Dawson, Eustis, Farnam, Loup City, Mitchell, Morrill, Oxford, Sheldon, and Wymore; 3 each to Chester, Emmett, Fairbury, Gothenburg, O'Neill, and Wahoo.

[26] The following consignments were made to New Hampshire points: 1 car each to Keene and Manchester.

[27] The following additional consignments were made to New Jersey points: 1 car each to New Brunswick and Plainfield; 2 cars to Elizabeth; 3 cars to Bayonne.

[28] The following consignment was made to New Mexico: 1 car to Raton.

[29] The following additional consignments were made to New York points: 1 car each to Amsterdam, Colden, and Ithaca; 2 cars each to Canastota, Jamaica, Melrose, Rockport, and Rome; 3 cars to Wellsville.

New York—Continued.	
Syracuse	26
Troy	7
Utica	10
Wilson	14
North Carolina: [30]	
Asheville	18
Charlotte	14
Fayetteville	4
Gastonia	4
North Dakota: [31]	
Beach	23
Bismarck	86
Cogswell	4
Cooperstown	5
Dickinson	10
Fargo	76
Grafton	14
Leeds	8
Mandan	15
Marmath	10
Minot	308
New Rockford	10
Oakes	6
Ransomeville	9
Rossville	17
Rugby	5
Stanley	6
Towner	4
Valley City	59
Wahpeton	6
Williston	13
Ohio: [32]	
Akron	106
Ashtabula	4
Bellefontaine	4
Canton	22
Cincinnati	124
Cleveland	194
Columbus	77
Dayton	17
Ohio—Continued.	
Lima	4
Toledo	60
Youngstown	10
Zanesville	5
Oklahoma: [33]	
Ardmore	8
Enid	6
McAlester	10
Muskogee	27
Oklahoma	132
Shawnee	14
Tulsa	110
Oregon: [34]	
Baker	7
Bend	4
Cornelius	5
East Portland	12
Five Points	4
Hood River	72
Medford	4
Newberg	8
Portland	165
Salem	7
The Dalles	140
Pennsylvania: [35]	
Altoona	9
Beaver Falls	4
Everson	5
Hazelton	4
Lehighton	8
Philadelphia	471
Pittsburgh	630
Scranton	22
Rhode Island: [36]	
Providence	55
South Carolina: [37]	
Anderson	8
Charleston	12
Greenville	18
Spartanburg	33

[30] The following additional consignments were made to North Carolina points: 1 car each to Linville, Rockingham, and Vilas; 2 each to Greensboro and Statesville; 3 each to Albemarle and Winston-Salem.

[31] The following additional consignments were made to North Dakota points: 1 car each to Bathgate, Berthold, Binford, Brantford, Brocket, Calvin, Carbury, Carrington, Casselton, Chaffee, Colgan, Curlew, Dazey, Deering, Drayton, Eckelson, Edinburg, Egeland, Enderlin, Epping, Fessenden, Finley, Flasher, Forestburg, Friend, Glen Ullin, Hankinson, Jamestown, Kelso, Kindred, Lakota, La Moure, Landa, Lidgerwood, Linton, Lisbon, McVille, Mantador, Mayville, Michigan, Nekoma, Noonan, Northwood, Oriska, Park River, Perth, Portland, Powers Lake, Reeder, Regent, Rock Lake, Sarles, Selfridge, Sherwood, Starkweather, Stirum, Strasburg, Streeter, Tolley, Tower City, Turtle Lake, and Warwick; 2 each to Alta, Cando, Dogden, Fullerton, Goldenvalley, Hatton, Inkster, Johnstown, Kensal, Lansford, Luverne, McClusky, Mott, Page, Sharon, and Sykeston; 3 each to Grand Forks, Hettinger, Hillsboro, Maddock, and Max.

[32] The following additional consignments were made to Ohio points: 1 car each to Findlay, Lando, and Wooster; 2 each to Lorain, Portsmouth, and West Lafayette; 3 each to Massillon and Springfield.

[33] The following additional consignments were made to Oklahoma points: 1 car each to Ada, Beulah, Bison, Blackstone, Blackwell, Booneville, Canute, Chandler, Crane, Custer City, Durant, Elk City, Fairview, Frederick, Grainville, Guthrie, Hobart, Hollister, Kiefer, Miami, Moore, Morris, Mounds, Okemah, Okmulgee, Pauls Valley, Stillwater, Tuttle, Tyrone, and Woodward; 2 each to Calumet, Cherokee, Chickasha, Dickson, Lawton, Perry, and Vinita; 3 cars to Cushing.

[34] The following additional consignments were made to Oregon points: 1 car each to Albina, Altus, Ashland, Bertha, Brandt, Corvallis, Eugene, Graham, Hermiston, Klamath Falls, Moro, Roseburg, and Yamhill; 2 each to Houlton and Nyassa; 3 each to La Grande and Pendleton.

[35] The following additional consignments were made to Pennsylvania points: 1 car each to Arnot, New Britain, and New Kensington; 2 each to Arnold and Erie; 3 each to Homestead and Lancaster.

[36] The following additional consignment was made to Rhode Island: 1 car to Woonsocket.

[37] The following additional consignments were made to South Carolina points: 1 car each to Greenwood and White Stone; 2 each to Charlotte, Rock Hill, and Union.

South Dakota:[38]	
Aberdeen	131
Artesian	4
Brookings	4
Deadwood	14
Devils Lake	6
Drake	12
Huron	6
Madison	6
Mobridge	11
Parker	5
Pierre	6
Plankington	5
Rapid City	16
Sioux Falls	39
Watertown	24
Tennessee:[39]	
Bristol	8
Chattanooga	23
Johnson City	4
Knoxville	11
Memphis	63
Nashville	29
Texas:[40]	
Abilene	8
Amarillo	4
Austin	22
Beaumont	17
Brenham	4
Cameron	4
Cisco	6
Corsicana	4
Dallas	179
El Paso	21
Fort Worth	121
Galveston	18
Greenville	13
Houston	138
Laredo	28
Marshall	5
Paris	24
Texas—Continued.	
Richland	4
St. Francis	4
San Angelo	10
San Antonio	64
San Benito	4
San Marcos	5
Sherman	8
Taylor	4
Tyler	33
Waco	113
Wichita Falls	16
Yoakum	5
Utah:[41]	
Salt Lake City	18
Vermont.[42]	
Virginia:[43]	
Lynchburg	9
Norfolk	47
Richmond	12
Roanoke	7
Washington:[44]	
Bellinger	15
Everett	55
Grand View	10
Kennewick	7
Kent	23
Mabton	5
North Puyallup	14
Olympia	117
Pasco	12
Puyallup	7
Seattle	569
Selah	16
Spokane	274
Sumner	153
Tacoma	102
Toppenish	5
Umatilla	14
Vancouver	119
Walla Walla	46

[38] The following additional consignments were made to South Dakota points: 1 car each to Bath, Bellefourche, Blunt, Brentford, Burke, Corsica, Delmont, Doland, Edgemont, Erskine, Ethan, Faith, Fedora, Freeman, Fulton, Groton, Hartley, Herried, Holmquist, Hoven, Howard, Hurdsfield, Hurley, Isabel, Kimball, Lake Preston, Lesterville, Mellette, Menno, Missinhill, Mount Vernon, Murdo, Oldham, Oneka, Ree Heights, Ruby, Savoy, Scotland, Selby, Sinai, Stickney, Tulare, Veblen, Viborg, Vilas, and Winner; 2 each to Alexandria, Arlington, Bridgewater, Canova, Chamberlain, Conde, Garretson, Highmore, Lead, Letcher, Parkston, Redfield, Rockham, Tripp, Volga, Webster, White Lake, and Wolsey; 3 each to Clark, Morristown, Vermilion, and Wessington.

[39] The following additional consignments were made to Tennessee points: 1 car each to Centerville, Glen Ellen, Humboldt, Norris, and Trenton; 2 each to Barnesville and Katherine; 3 cars to Dyersburg.

[40] The following additional consignments were made to Texas points: 1 car each to Allendale, Alpine, Alvin, Ballinger, Boden, Bonham, Brownsville, Burnside, Clear Creek, Coleman, Corpus Christi, Cuero, Easterly, Eastland, El Campo, Gainesville, George, Giddings, Goodwin, Hardin, Herrington, Hartley, Hasse, Hershey, Hunter, Huntsville, Jordan, Lacy, Lester, Lufkin, Manning, Mason, Mexico, Mineola, Nebraska, New Braunfels, Pescos, Pleasanton, Pullian, Somerset, Stamford, Sulphur Springs, Sylvan Grove, Terrell, Timber, and Uvalde; 2 each to Athens, Bay City, Bryan, Flatonia, Granger, Llano, McKinney, Mineral Wells, Nacogdoches, Palestine, Paradise, Seymour, Temple, Weatherford, and Yorktown; 3 each to Brownwood, Eagle Pass, Lubbock, and Port Arthur.

[41] The following additional consignments were made to Utah points: 1 car each to Bingham, Greenriver, Hyde Park, Layton, Lehi, Petersboro, and Stoddard; 2 cars to Roy; 3 cars to Richfield.

[42] The following consignment was made to Vermont: 2 cars to Rutland.

[43] The following additional consignments were made to Virginia points: 1 car to Appalachia; 2 cars to Newport News; 3 cars to Lemon.

[44] The following additional consignments were made to Washington points: 1 car each to Almira, Argo, Borup, Cascade, Cashmere, Cle Elum, Dryden, Edgeley, Eltopia, Fort Wright, Hillyard, Index, Knapp, Lemona, Malden, Malone, Ravenna Park, Republic, Rochester, and Wells; 2 each to East Farm, Ellensburg, Hoquiam, Lind, Ritzville, Sandy Point, and Wenatchee; 3 cars each to Aberdeen and Centralia.

Washington—Continued.	
Wallula	7
Wapato	17
Yakima	448
Zillah	115
West Virginia.[45]	
Wisconsin:[46]	
Appleton	5
Eau Claire	11
Janesville	5
La Crosse	17
Madison	10
Marshfield	8
Milwaukee	124
Oshkosh	7
Richland Center	4
Wisconsin—Continued.	
Stevens Point	6
Superior	10
Wausau	4
Wyoming:[47]	
Casper	23
Cheyenne	297
Crosby	5
Gillette	4
Kemmerer	4
Laramie	79
Rawlins	4
Riverton	4
Rock Springs	4
Sheridan	13
Thermopolis	4

CANADA.

Alberta:[48]	
Calgary	20
Edmonton	17
Lethbridge	4
British Columbia:[49]	
Cut Bank	16
Grand Forks	18
Vancouver	25
Manitoba:[50]	
Brandon	4
Winnipeg	36
New Brunswick:[51]	
St. John	4
Nova Scotia:[52]	
Ontario:[53]	
Hamilton	5
Kingston	4
Toronto	52
Quebec:	
Montreal	22
Quebec	4
Saskatchewan:[54]	
Moose Jaw	12
Prince Albert	4
Regina	26
Saskatoon	12
Weyburn	14

WEST INDIES.

Cuba:	
Havana	17

[45] The following consignments were made to West Virginia points: 2 cars each to Huntington and Litchen; 3 cars to Bluefield.

[46] The following additional consignments were made to Wisconsin points: 1 car each to Antigo, Blanchardville, Cody, Kenosha, Merrill, Oneida, Prescott, Rosholt, South Range, and Wild Rose; 2 each to Green Bay, Jefferson, Rhinelander, Ripon, River Falls, Sydney, and Winter; 3 each to Beloit, Racine, and Washburn.

[47] The following additional consignments were made to Wyoming points: 1 car each to Diamondville, Dietz, Evanston, Frontier Park, Glenrock, Hereford, Lingle, Moorcroft, Ruck, and Wheatland; 2 each to Lander, Powell, and Upton.

[48] The following additional consignments were made to Alberta points; 1 car each to Big Stone, Clairmont, Fitzgerald, Killam, and Redcliff; 2 cars to Pocahontas; 3 cars to Medicine Hat.

[49] The following additional consignments were made to British Columbia points: 1 car each to Fernie, Hulatt, Huntingdon, Seton, and Three Forks; 2 cars to Milner; 3 each to Sidney and Victoria.

[50] The following additional consignments were made to Manitoba points: 1 car to Leighton; 2 cars to Melita; 3 cars to Elm Creek.

[51] The following additional consignments were made to New Brunswick points: 1 car to Humphreys; 3 cars to Salisbury.

[52] The following consignment was made to Nova Scotia: 1 car to Tomkinsville.

[53] The following additional consignments were made to Ontario points: 1 car each to Aberdeen, Dublin, Millbank, North Bay, Port Arthur, Prince Albert, Redmond, Rockland, St. Thomas, Sudbury, and Welland; 2 each to Bainsville, Chippewa Falls, Hillsbury, and Omemee; 3 cars to London.

[54] The following additional consignments were made to Saskatchewan points: 1 car each to Alameda, Canora, Carnduff, Chaplin, Fernwood, Kerr-Robert, and Rutan; 3 cars to Swift Current.

EXHIBIT No. 10.

Comparison of apple exports by months.

Months.	1916–17	1917–18	1918–19	1919–20
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*
September	129,503	24,720	14,942	34,619
October	346,014	68,985	90,780	115,715
November	378,320	150,644	104,572	213,270
December	342,572	190,390	160,035	142,806
January	203,904	33,776	213,107	161,157
February	130,666	26,232	493,996	90,215
Total	1,530,979	494,747	1,077,432	757,782

EXHIBIT No. 11.

To make a comparison of the rate and destination competition among the three main apple-producing sections of the United States, the mileage and freight rate from Spokane, Wash., Rochester, N. Y., and Winchester, Va., are shown from those points to nine of the principal terminal markets of the country. These rates were in effect on March 31, 1920, but are given merely as a matter of information and can have no standing in adjusting freight charges with carriers. For that purpose official quotations from tariffs on file with the Interstate Commerce Commission and with State commissions should be secured from carriers' representatives.

To—	Spokane, Wash.		Rochester, N. Y.		Winchester, Va.	
	Distance (miles).	Rate per 100 pounds.	Distance (miles).	Rate per 100 pounds.	Distance (miles).	Rate per 100 pounds.
Chicago, Ill	1,835	$1.25	605	$0.31	770	$0.42
Detroit, Mich	2,118	1.25	322	.24½	612	.32
Indianapolis, Ind	2,019	1.25	536	.29½	664	.39
Cincinnati, Ohio	2,120	1.25	514	.27½	553	.36
Pittsburgh, Pa	2,303	1.25	286	.21½	302	.24
Buffalo, N. Y	2,371	1.25	69	.11½	435	.27
Philadelphia, Pa	2,652	1.25	369	.22½	223	.25
New York, N. Y	2,744	1.25	370	.22½	315	.27
Boston, Mass	2,868	1.25	428	.25	548	.29½

The refrigeration charge on apples per car prior to March 1, 1920, from Spokane to these points was as follows: Chicago, $60; Detroit, Indianapolis, Cincinnati, Pittsburgh, and Buffalo, $65; Philadelphia and New York, $70; Boston, $75.

The tariffs named a heating charge from Spokane to Chicago only, and this rate, prior to March 1, 1920, was $27.

The refrigeration charges on shipments originating in the East vary, depending on the individual tariffs of the carriers.

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E. W. NELSON, Chief.

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WILD DUCKS AND DUCK FOODS OF THE BEAR RIVER MARSHES, UTAH.

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INTRODUCTION.

The economic value of wild ducks and geese as a source of sport, an incentive to healthful outdoor recreation, and an adjunct to the food supply is universally recognized in this country. Legislative measures for the protection of these birds, designed to enable them to hold their own against an ever-increasing army of gunners, have multiplied and have added to the restrictions on hunting as need for them has been realized by sportsmen and persons interested in birds in general. These regulations, however, have not been sufficient to maintain the birds in their former abundance. Regions that once were the summer homes of myriads of wild ducks have been drained and placed under cultivation, and extensive areas where the birds at one time bred are now populous farming communities. The changes have crowded out former avian residents and have served in a corresponding degree to reduce their numbers. Realization of these

NOTE.—This bulletin is a report on the abundance, food supplies, and general conditions affecting the wild ducks and geese breeding on the Bear River marshes in Utah, or frequenting this region at other times of the year, before their migrations to other parts of the United States. It is for the information of sportsmen and others interested in waterfowl.

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facts has led more recently to the adoption of other compensatory measures to encourage our larger waterfowl. A number of extensive marsh areas have been made permanent refuges under the guardianship of the United States Department of Agriculture, and many private preserves, some of them formed by artificial means, have been established, where the birds are protected while nesting and are shot under more or less rigid local restrictions during designated open seasons for hunting. As a means of cooperating in such efforts to maintain and increase the numbers of our waterfowl, the Biological Survey has undertaken investigations of the general conditions under which wild ducks live and thrive, coupled with counts of the numerical abundance of these birds in different areas varying in character. Much of this needed information has been gained through studies of the foods and general activities of our native wild ducks. Several bulletins dealing with favored duck foods that may be introduced or propagated in many areas where they are at present unknown have been issued,[1] and one enumerating the breeding ducks and the available duck foods of lakes in the sandhill region of Nebraska has been published.[2]

During three summer seasons the writer was engaged in field work dealing with wild ducks in the Bear River marshes in Utah, spending the greater part of the time from July 15 to October 23, 1914; May 18 to October 20, 1915; and May 15 to October 25, 1916, on this work. Extended observations and notes were made during the entire period, and in 1916 a count of the breeding ducks found in this area was made in as detailed a manner as practicable. In the following report is embodied a general account of observations and studies on the numbers and abundance of waterfowl, their food supplies, and the general conditions under which such birds live in that region.

GENERAL ACCOUNT OF THE BEAR RIVER MARSHES.

Bear River, the largest of the three main tributaries draining into Great Salt Lake, flows into the northern end of that body of water. Before reaching the saline waters of the lake proper the main stream of the river (Pl. I) breaks up into several branches, which in turn subdivide into minor channels, the whole forming a great delta embracing marshes grown with dense vegetation and open barrens of alkaline earth or mud. The silt-charged stream of the main river has filled in around its mouths, leaving two main lake

[1] McAtee, W. L., Eleven Important Wild-Duck Foods: U. S. Dept. Agr. Bull. 205, pp. 25, figs. 23, 1915; McAtee, W. L., Propagation of Wild-duck Foods: U. S. Dept. Agr. Bull. 465, pp. 40, figs. 35, 1917.

[2] Oberholser, Harry C., and W. L. McAtee, Waterfowl and Their Food Plants in the Sandhill Region of Nebraska: Part I, Waterfowl in Nebraska; Part II, Wild-duck Foods of the Sandhill Region of Nebraska: U. S. Dept. Agr. Bull. 794, pp. 77, pls. 5 (incl. 1 map), 1920.

areas, called respectively North Bay and South Bay, that open into the arm of the lake proper, known as Bear River Bay. Three main channels and one smaller one flow into North Bay and three overflows or branches supply South Bay. The space encompassed by these is wet and swampy. A large area known as Hansens Island, lying between the lower portions of the two bays, is cut by an old channel, formerly connected with the river but now separate, except where a canal (made by the Bear River Club in the fall of 1914) gives access to it. A series of lakes and sloughs, formerly parts of the river channel, lie parallel to Bear River from Corinne well down across the flats. Below these a large artificial lake, known as Chesapeake Bay, has been formed by damming Woods Creek. On the south side of the river below Brigham City is an extensive series of sloughs that drain into the Willard Spur, an arm of Bear River Bay. These are all included in the region covered by the following report. At the present time a large part of the water in Bear River is diverted during the summer season into irrigation canals, so that much of the water in the lower course of the stream comes from seepage and waste from the terminal ditches. North Bay receives water from the Malad River through a series of channels controlled by the Bear River Club, and in addition is augmented somewhat by drainage from the small streams known as Salt Creek and Blue Creek.

The entire area under consideration offers great inducements for waterfowl in the form of abundant food and attractive bodies of water. The banks of Bear River immediately below Corinne are cultivated, but along the lower course of the river, except in a few localities, the soil is little suited for farming, and there are few persons resident on it throughout the year. Near Corinne tree growths of box elder and cottonwood are found, but along the river below that point the main wooded growth is composed of black and gray willows (*Salix amygdaloides* and *Salix exigua*). These form a narrow band bordering either bank and extend down to the marshes. On either side are broad, level flats where alkaline conditions are too severe for much plant growth. These are bordered by extensive meadows of salt grass and are fringed with scattered plants of the curious fleshy-stemmed salt weed known as samphire.

DISCUSSION OF WATERFOWL.

BREEDING SPECIES AND THEIR ABUNDANCE.

Eleven species of ducks and the Canada goose are now known to nest on the Bear River marshes. Eight of the ducks are of common occurrence. Arranged in order of their abundance as breeding birds these are the redhead, cinnamon teal, mallard, shoveler or spoonbill,

gadwall, ruddy duck, pintail, and green-winged teal. The widgeon and blue-winged teal are only tolerably common, and the canvasback, a species that is decidedly rare in summer, is included on the authority of A. O. Treganza, of Salt Lake City; one additional species, the lesser scaup duck, is probably casual in its nesting here. On June 12, the writer, with his assistant, T. E. Griesa, found a male of this species near Long Point on North Bay. This bird passed and repassed a dozen times or more, circling about as ducks do when their nests are approached. Other scaup ducks were seen during the entire summer, but these birds remained in the open bays below the marshy areas and it was certain that they were nonbreeding individuals. It is a common thing for a few ducks of this species to pass the summer in regions far south of their breeding range, but in the instance mentioned there is little question that the male seen was a breeding bird.

In the enumeration of the breeding ducks of this area the entire region described under the general account of the Bear River marshes was covered as carefully as practicable between May 15 and June 26. Dependence was placed only in part upon birds seen in open water; each channel was traversed by boat or on foot, and extensive marsh areas were tramped in search for nests (Pl. II, fig. 1) or nesting birds. In some cases favorable localities were covered two or three times in order to check the results obtained. Ducks continue to breed until a much later date, but these delayed birds are probably those whose first nests have in some way been destroyed. Cinnamon teals only four or five days old were seen August 8, and redheads less than a third grown were common as late as September 7; a large number of young redheads were unable to fly until after September 25. An attempt to continue a count of the breeding ducks in this region after July 1, however would fail entirely to give an adequate conception of the number present earlier in the season.

The figures given in tabulating the final results of the counts are approximate; the enumerations were conservative, and it is believed that the results are sufficiently accurate, allowance being made for not more than 40 per cent of error. Greater accuracy can hardly be claimed in work of this sort except on small areas covered minutely. Ducks are adept at hiding, especially where vegetation is heavy, and often allow persons to pass within a few feet without flushing. Thus the examination of marsh areas through glasses from a distance is unsatisfactory, as many birds readily pass unnoticed. The results of the enumeration of breeding birds are given in the following table, the species being arranged in the order of their abundance:

MAIN CHANNEL OF BEAR RIVER NEAR ITS MOUTH.

Marshy areas and alkaline flats are shown on either side and in the distance.

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FIG. 1.—NEST OF REDHEAD.

The redhead is the most common of breeding ducks in the Bear River marshes. This nest is about 18 inches high and has a pathway built up to one side.

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FIG. 2.—GREEN-WINGED TEAL "FLAPPER."

A molting female, the new flight feathers reappearing to replace those dropped.

Species.	Estimated number of breeding pairs.	Species.	Estimated number of breeding pairs.
Redhead	1,725	Green-winged teal	50
Cinnamon teal	800	Widgeon	10
Mallard	300	Blue-winged teal	10
Shoveler, or spoonbill	250	Scaup duck, or bluebill	[1] 1
Gadwall	200		
Ruddy duck	175	Total	3,650
Pintail	130		

[1] Not included in total.

As a conservative estimate each pair of ducks may be expected to rear 5 young, and as the average brood varies from 7 to 12 individuals this allows for considerable mortality among ducklings. Adding the survivors to the original pair, the total number of native birds on this marsh at the end of the breeding season should be approximately as follows:

Species.	Individuals.	Species.	Individuals.
Redhead	12,075	Pintail	910
Cinnamon teal	5,600	Green-winged teal	350
Mallard	2,100	Widgeon	70
Shoveler, or spoonbill	1,750	Blue-winged teal	70
Gadwall	1,400		
Ruddy duck	1,225	Total	25,550

In addition to the ducks, about 100 pairs of Canada geese breed on these marshes. Allowing 3 young as the average number brought to maturity by this species, there would be a total of 500 birds at the close of the season. The nesting season for these geese is practically over by May 15, and their numbers were estimated from observations made before they disappeared in the lower marshes for their annual molt.

The figures given above are approximations, but it is believed that they are not far from the truth. From them it is learned that this marsh area produces between 25,000 and 30,000 ducks in the average season, as in 1916. The question may arise as to the propriety, in arriving at a total, of adding the original pair of birds to the young produced. It is probable that a large part of the adult ducks that die from natural causes (as opposed to shooting) do so toward the close of the breeding season and during the molt that follows. Exhausted by the calls made upon their strength by the needs of the nesting season, they have not sufficient vitality to carry them through the annual molt that takes place as soon as they are freed from their parental duties. In the estimates, however, sufficient allowance has been made for mortality among the young to cover losses among the adults as well, so that the totals given should

represent the actual number of birds produced from this marsh that are available to sportsmen there and elsewhere.

HABITS AND ACTIVITIES AFTER THE NESTING SEASON.

In the course of studies in this region it was learned that the great marshes in the delta of Bear River not only offer a favorable breeding ground for many pairs of ducks, but also that they are even more important as a refuge and feeding ground for a much larger number of birds after these are freed from family cares in other regions. To maintain themselves in condition, all species of birds must renew their bodily covering of feathers at least once each year, while many forms molt partially or entirely at shorter intervals. This usually is a gradual process, as only a few feathers drop out at one time and are replaced by new ones. One or two feathers fall in either wing at approximately the same time and more are not lost until the first ones are partly grown. By this continuous renewal the powers of flight of the ordinary bird are not seriously hampered and it is able to feed, fly about, and evade its enemies as usual.

In wild ducks and geese, however, the process is entirely different. In common with grebes and rails, the ducks and other anserine birds drop all the feathers of the wings and tail at about the same time, and for a period of four or five weeks are wholly unable to fly. At this time they must have access to large marsh areas where they may find an abundance of food without exposing themselves unduly to the attacks of enemies. Many thousand ducks from other areas gather in the Bear River marshes each season for this purpose, greatly augmenting the numbers of those that breed there.

In all the species of ducks that frequent this area in summer, except the ruddy duck, the males nearly always desert their mates as soon as the complete set of eggs has been deposited and incubation has begun. During three summers spent on Bear River the writer saw many hundreds of broods of wild ducks, but, except in the case of ruddy ducks, not more than ten instances were observed where drakes accompanied the young. The male ruddy duck, like the Canada goose, usually stays with the female until the ducklings are well grown, and it is common to see one at the head of a brood of dusky young, swimming with chest and neck puffed out and tail spread. Occasionally a male gadwall, shoveler, or mallard may accompany a female and her brood, but such occurrences are rare.

After the pairing season the drakes begin to join in flocks, and large bands of these males gather to feed and rest on the great open bays. At this time they are in bright, showy plumage, but early in summer a change takes place. The body feathers are replaced by a plain dull plumage more or less resembling that of the female,

and entirely different from the winter dress. This is known as the "eclipse" plumage and is found in all of the ducks that occur here except the ruddy duck. Soon after going into the eclipse plumage the drakes drop their wing and tail feathers, and then hide in the marsh growth until again able to fly. So well do they keep concealed that they are seldom seen, and few local sportsmen or others are acquainted with this peculiar habit, while persons who may happen to see them usually consider them young birds because of their bare wings Ducks in this flightless condition are known as "flappers." In working through the marshes they may be heard quacking and feeding in every direction, and if one is startled it flaps off at a rapid rate and hides so well that it can not be found. At night they come out to feed in the bays and lakes, but retreat again to the shelter of the rushes at daybreak. Most female ducks are busied with their young during the period that the males are molting into the eclipse plumage, but soon after the ducklings can care for themselves, the females join the other ducks in the bays and in turn soon shed their flight feathers. (Pl. II, fig. 2.) Most of the female ducks are later in their molt than the males, and in the case of birds whose first nest is destroyed so that they rear a second brood the molt may be delayed until late in summer or early in fall. Individuals late in molting may be found commonly in the Bear River marshes through the month of September and many are still in this condition after the opening of the hunting season on October 1.

In September the drakes begin to molt their body plumage again and come out in the bright-colored dress by which they are known in winter and spring. Sportsmen often ask why more old drakes are not shot at the beginning of the hunting season. The apparent lack of old males is due to the fact that they are confused with the immature birds from their piebald, patchy appearance as they change from the eclipse dress into full plumage. Adult female ducks, especially of pintails and green-winged teals, killed during the first half of October, nearly always have many pin feathers coming in on the body, due to their late molt as compared with the drakes. This fact is often remarked by the duck pickers who pluck the thousands of birds brought in to the gun clubs, and has been verified by the writer from personal observation of many hundreds of ducks.

From the foregoing it may be seen that while the delta of Bear River furnishes a breeding ground for many waterfowl, it is of even greater importance as a refuge during their annual molt to other individuals that have nested at unknown distances from the marsh. The drakes begin to come in for this purpose early in the season, the male pintails being the first to make their appearance in numbers. On June 14, 1915, a flock of 500 was found at the upper

end of South Bay, and a week later there were many hundreds. Birds that were shot for examination had the genital organs greatly enlarged, showing that they had finished breeding recently. They began molting into the eclipse plumage at once, and the mud flats where they rested during the day were strewn with cast-off feathers. In 1916 pintails appeared even earlier in the season; on June 7 about 100 drakes were found in South Bay, while on the following day their numbers had been augmented to approximately 1,000. On June 14 a flock of male pintails in the region known as Lands End was estimated to contain between 2,500 and 3,000 birds. With these were only two or three females. As it was estimated that in 1916 there were only 130 pairs of breeding pintails in this entire marsh area, it will be seen that there was a great influx of males at this time. Where these summering birds nest is of course uncertain, but they must gather here from great areas that apparently lie largely outside of Utah. Though the pintails arrive first, they are soon joined by many mallards and shovelers, of which a part come from the surrounding marsh and a part from other regions. These males steadily increase in number and, joined later by broods of immature birds, form great banks of ducks that rest during the day on the shallows covering the mud flats.

The Canada geese follow a different procedure in their molt. They nest early, and as soon as their young are strong enough they take them far down on the flats. The adult birds are more or less in evidence until about May 25, when most of them disappear. At this season adults and young frequent the great growths of rushes (*Scirpus paludosus*) in the lower marsh, and while hidden here the adults molt their flight feathers. In 1916 a number of families of geese lived in the lower part of Hansens Island through this period of molt. In feeding they apparently ranged over considerable areas and at night came into dense green rush growths near the open bays, where they slept close together on small hummocks. At this season they were warier than ever and seldom was one seen. In the heavy growths of rushes their roosting places, marked by broken, trampled vegetation and great piles of excreta, were found frequently; and goose tracks were often seen in small channels and runs through the marsh, so fresh that mud stirred up as the geese passed was still held in suspension in the water, but the birds themselves kept well hidden. By molting at this early date the wing feathers of the adults were renewed by the time the young were able to fly, and old and young were thus able to remain together. Geese begin to reappear on the marsh between July 1 and 4, and by July 10 small flocks with their musical call notes were again a familiar morning and evening feature of the life of the marsh.

FALL MIGRATION.

The number of wild ducks on the Bear River marshes continues to grow until about the 1st of September; during the latter part of August the increase is rapid, as hordes of young ducks that have been reared on the uplands and along small streams and lakes in the mountain valleys begin to arrive. Between the 1st and the 10th of September there is a sudden diminution in the numbers, and at this time fully two-thirds of the ducks leave the marsh and migrate to other regions, apparently far distant. The great mass of cinnamon teals and redheads leave the marsh then and with them go many pintails and others. The sudden disappearance of numbers of the ducks is noticeable, and can not fail to attract the attention of one closely in touch with the daily course of the wild life on the marsh. The exodus seems to take place at night, and bays and lagoons that one day are banked solidly with rank after rank of resting waterfowl may 24 hours later show individuals only in tens where before they were represented in hundreds. That this migration is to distant points seems certain. A drake pintail that had been banded and released at a field laboratory near the Duckville Gun Club on these marshes September 4, 1916, was killed 11 days later not far from Glasgow, Mont.

Ducks again begin to gather on the flats, however, and by the opening of the hunting season enormous numbers are once more present. These are composed of young birds and adults that have come in from other regions, of young from late-hatched broods on these marshes, and of adults that after completing the molt have come out from the seclusion of the rushes. There is considerable movement night and morning among these birds, but they have no such regularly established lines of flight at this time as they do after two or three days of shooting. From October 8 to 15 many additional ducks come in from the north, their arrival depending upon cold storms that drive them from more northern localities. From this time on the migration from the north is steady. Several species arrive that are rare or absent during the breeding season and so add to the duck population of the marsh. The canvas-back is fairly common after October 10, while the snow goose, buffle-head, and golden-eye, or whistler, are present in some numbers after October 15. Lesser scaup ducks, or bluebills, come at about the same time, but are not common until a week later. Besides these a few other species appear in very small numbers. The ducks are said to remain in fall as long as there is open water in the channels or bays, but most of them are reported to leave finally between December 1 and 15. The date of departure varies with the year and may be earlier or later, according to the season.

THE SHOOTING SEASON.

By referring to the list of breeding ducks given on page 5, it will be seen that redheads and cinnamon teals comprise more than two-thirds of the total number of ducks that breed on the Bear River marshes; those familiar with conditions during the hunting season, however, recognize that these two species furnish a very small percentage of the ducks that are killed each fall. The bulk of the redheads leave as soon as the adult ducks have completed their molt and are able to fly, and by September 15 the greater part of them are gone. Most of the cinnamon teals leave at the same time and few of these are killed. The birds that remain during the hunting season are immature birds from late broods, unable to fly at the time of the great migration of their fellows. These stay until late in the season and may be present until the bays are closed by ice. The early migration of these ducks has been used by a few as an argument for opening the hunting season during part or all of the month of September. To make the opening date earlier than October 1, however, would be a great mistake, as it would inevitably lead to killing a large number of young ducks before they are in condition, while at the same time many of the adult birds would be molting and so would not offer sport or be of much value as food. It is fortunate that the majority realize this and are content with present conditions.

FOOD SUPPLIES ATTRACTIVE TO WILD DUCKS.

In order to attract and support a large number of wild ducks, a marsh area, besides affording a retreat from enemies, must offer an abundant store of food. If attractive food supplies are available, ducks will gather and linger in spite of shooting and other disturbances. In the Bear River marshes the two prime requirements of food and shelter are met to the fullest degree. The areas of marsh and open bay are broad enough to harbor a large number of birds in comparative safety and to allow them to shift from place to place when disturbed, while the food supplies apparently are boundless. Collections of plants and seeds were made here during three seasons and those foods that have been found attractive to wild ducks through observations made in the field, supplemented by the examination of stomachs of birds killed in the marshes, are enumerated in the following paragraphs.

VEGETABLE FOODS.

There are two plants present in great abundance in the area under consideration upon which ducks depend largely for their staple vegetable food—the sago pondweed and the bayonet grass. Sago pond-

weed (*Potamogeton pectinatus*), known familiarly to hunters as "potato moss" or "duck moss," is the dominant plant of the open bays and sloughs, where it grows submerged in the water. This plant springs from a tuber buried from a few inches to a foot or more in the mud. It appears in the bays in abundance during the last part of May and by the end of June has filled the greater part of the open water with dense growth. During July it produces a mass of hard seeds, and then a great deal of it dies down in the bays at the mouth of the river and breaks off at the roots, to drift out into the lake and leave the bays bare open expanses with a smooth mud bottom. In other places, as the Chesapeake Bay, the summer growth sinks to the bottom and remains throughout the fall. The sago pondweed is one of the best of known duck foods, as all parts of the plant, the tubers, stems, leaves, and seeds are palatable and are eagerly sought as food by wild ducks. The ducks dig great "duck holes" in the mud of the open bay from 1 to 20 or 30 feet wide and from a few inches to a foot deep, in search of the succulent tubers. These roots furnish a great part of the food of the pintails and mallards on the marsh in fall and are eaten eagerly by most if not all of the other ducks. In summer and early fall the stems and leaves also are sought.

Sago pondweed seems to be strongly resistant to the action of alkalis, as it will grow in areas where the soil is impregnated with salts, though in such places the growth of the plant may be somewhat stunted. This plant also thrives in the fresher water of channels and sloughs, and here makes a very heavy growth. Its tubers are frequently as large as a kernel of corn, and, if the sprout is discarded, they have a pleasant, nutlike flavor. They persist even during years when the bays are dry during summer, and so insure a supply of this food the following year. After the plants have died down in the lower bay the seeds still remain, and often are washed up in long windrows on the mud bars. Green-winged teals as well as other ducks are fond of these, and in fact hardly a duck stomach was examined in late summer and fall that did not contain a few of them. Bits of gravel or other hard particles are essential to digestion of food in ducks, but in alluvial deposits like those at the mouth of Bear River, situated far from the foothills, small pebbles and grit are difficult to secure. The hard seeds of the "potato moss" are firm enough to aid in grinding up other softer foods, while at the same time they are themselves digested, so that they serve a double purpose in the economy of the birds concerned.

The second plant, equal in importance as a duck food to the one just described, is the bayonet grass, rush, or tule (*Scirpus paludosus*). (Pl. III, fig. 1.) This is the dominant plant of the marsh growth and, except where saline conditions in the soil are too strong, covers the

entire marsh. It grows usually to a height of from 18 inches to 2 feet or more, according to the locality. The plant has a three-sided stem, from which sheathlike leaves spring at different levels, and it grows from a bulb as large as a walnut. The head bears from 6 to 20 or more ovate, flat brown or blackish seeds with sharp, pointed tips. These seeds begin to mature in July and August and are a favorite food of ducks, especially of those species known as the shallow-water or river ducks. The stems of the tules themselves are used by hunters in building blinds. During late summer these growths of rushes furnish much of the cover that protects the waterfowl during the molt and later the ducks visit them for food. Most duck stomachs examined contained from one to many of the seeds of this plant.

Bayonet grass is of great importance as a food supply, as, though many of the seeds drop to the ground in fall, a good proportion remain in the seed heads until the following year and persist in abundance as late as May and the first part of June. In this way they furnish a food supply late in fall when other stocks are sealed with ice, and in spring these seeds again are available to the ducks returning from the south.

Other plants, also present in abundance, furnish valuable foods for ducks. Samphire or salicornia (*Salicornia rubra*) covers great areas of otherwise barren flats, and in less saline soils a saltbush known as lamb's-quarters, or duck lettuce (*Atriplex hastata*), is abundant. In fall the ducks eat the fleshy leaves and stems of these plants to a considerable extent. The seeds of a dock (*Rumex crispus*) are relished, as are the seed heads of the abundant salt grass (*Distichlis spicata*). In very saline waters a musk grass (*Chara* sp.) and ditch grass (*Ruppia occidentalis*), both favored duck foods, are common, and there are a number of other species of plants whose seeds, leaves, or stems are relished which are likewise common though less abundant than those enumerated above.

A complete list of the plants available as duck foods in this area, with some indication of their occurrence, follows:

Species Growing Submerged.

Sago pondweed (*Potamogeton pectinatus*). Abundant.
Ditch grass (*Ruppia occidentalis*). Common.
Musk grass (*Chara* sp.). Common.
Long-leaved pondweed (*Potamogeton americanus*). Common near Corinne.

Floating Plants.

Duckweed (*Lemma* sp.). Fairly common in fresh water.
Water smartweed (*Polygonum amphibium*). Fairly common.
White water crowfoot (*Batrachium trichophyllum*). Fairly common.

B17063

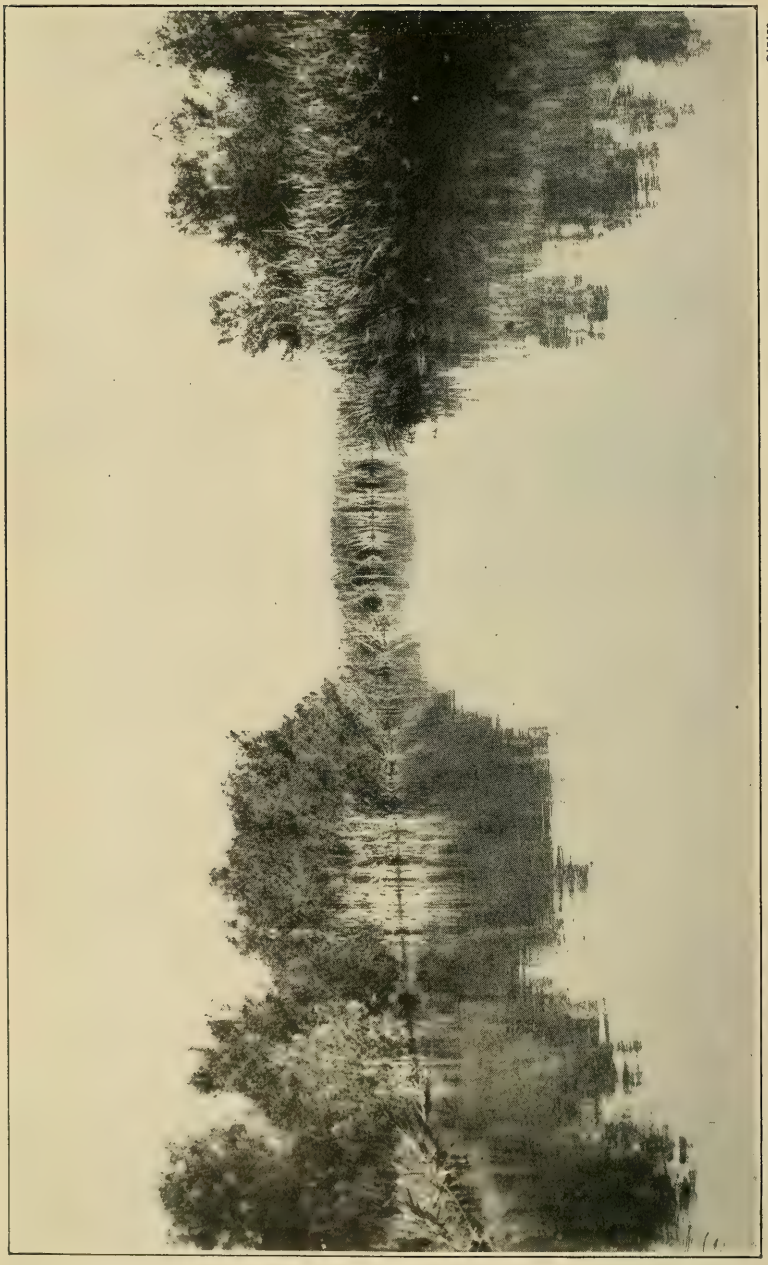
FIG. 1.—TYPICAL MARSH GROWTH OF TULE, OR BAYONET GRASS (SCIRPUS PALUDOSUS).

The seeds of this plant furnish a valuable food for wild ducks.

B17155

FIG. 2.—GROWTH OF CANE (PHRAGMITES PHRAGMITES).

These plants furnish cover for ducks and their young and are used also by sportsmen in constructing boat blinds during the hunting season.



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ONE OF THE LARGER BRANCHES INTO WHICH BEAR RIVER DIVIDES AT ITS MOUTH.

Typical vegetation—black willow (*Salix amygdaloides*) on left, and broad-leaved cat-tail (*Typha latifolia*) on right.

SHORE AND MARSH PLANTS.

Bayonet grass (*Scirpus paludosus*). Abundant.
Bulrush, round tule (*Scirpus occidentalis*). Common.
Olney bulrush (*Scirpus olneyi*). Common in the Salt Creek marsh.
Wire grass (*Eleocharis palustris*). Locally common.
Bur reed (*Sparganium eurycarpum*). Fairly common.
Arrow-grass (*Triglochin maritima*). Common.
Rush grass (*Sporobolus airoides*). Common.
Beard grass (*Polypogon monspeliensis*). Common.
Bent grass (*Agrostis alba*). Common.
Cord grass (*Spartina gracilis*). Fairly common.
Slough grass (*Beckmannia erucaeformis*). Fairly common.
Salt grass (*Distichlis spicata*). Abundant.
Goose grass (*Puccinellia nuttalliana*). Fairly common.
Brome grass (*Bromus tectorum*). Fairly common.
Foxtail (*Hordeum jubatum*). Abundant.
Wild barley (*Hordeum cussoneanum*). Fairly common.
Wild rye (*Elymus condensatus*). Fairly common.
Bog rush (*Juncus torreyi*). Fairly common.
Dock (*Rumex crispus*). Common.
Knotweed (*Polygonum incarnatum*). Fairly common.
Knot grass (*Polygonum aviculare*). Fairly common.
Burro weed (*Allenrolfea occidentalis*). Common.
Samphire (*Salicornia rubra*). Abundant.
Utah samphire (*Salicornia utahensis*). Common.
Salt bush, orache (*Atriplex hastata*). Abundant.
Goosefoot (*Dondia erecta*). Common.
Sandwort (*Tissa sparsifolia*). Common.
Buttercup (*Ranunculus eremogenes*). Common.
Trailing buttercup (*Halerpestes cymbalaria*). Common.
Yellow cress (*Radicula hispida*). Common.
White sweet clover. (*Melilotus alba*). Common.
Yellow sweet clover (*Melilotus officinalis*). Common.
Willow herb (*Epilobium adenocaulon*). Common.
Black saltwort (*Glaux maritima*). Common.
Heliotrope (*Heliotropium xerophilum*). Common.
Germander (*Teucrium occidentalis*). Common.
Mint (*Mentha penardi*). Common.
Cocklebur (*Xanthium echinatum*). Common.
Sunflower (*Helianthus nuttalli*). Common.
Pitchfork (*Bidens glaucescens*). Common.
Wild lettuce (*Lactuca integrata*). Common.
Blue lettuce (*Lactuca pulchella*). Common.
Spring sow thistle (*Sonchus asper*). Common.

All the plants enumerated contribute more or less to the food of the wild ducks in the marshes under consideration. There are in addition other plant growths present that, while not of value for their production of food, are abundant enough to serve as cover plants that furnish shelter and protection. Among these may be mentioned the broad-leaved and narrow-leaved cat-tails (*Typha latifolia* and *Typha angustifolia*), cane (*Phragmites phragmites*), gray willow

(*Salix exigua*), and black willow (*Salix amygdaloides*). (Pl. III, fig. 2, and Pl. IV.)

It is thus evident that the conditions found in the Bear River marshes leave little to be desired in the way of duck-food plants. In other regions improvement frequently may be brought about by introducing suitable plants for cover and for additional food supply. These marshes are so favored that artificial introduction of plants would not seem to be needed.

Among plants not found there, but considered valuable duck foods and possible of introduction, is wild celery (*Vallisneria spiralis*), as this plant can grow in brackish water. Whether such introduction would be successful can be ascertained only by experiment. This plant grows submerged and to thrive would require the deeper situations, as in certain channels in the upper sloughs, or in the Chesapeake Bay. Wild rice (*Zizania palustris*), the only other plant of importance that might be considered, can not endure salt to any extent, so that the alkaline waters and soils of Bear River would preclude its successful introduction, except possibly in certain small, restricted areas. In the long run, without much doubt, it will be found that the present marsh vegetation is best suited to these extensive flats. Soil conditions, as regards alkalinity, change and shift annually with changes in the water level of the lake itself, and with the volume of stream flow in Bear River. The marsh vegetation advances and retreats year by year, adjusting itself according to certain limits of tolerance for alkalis, in one place extending its bounds and in another being killed out and forced to withdraw. At present the tendency is for the tule growth in the lower part of the marsh to be driven back, while extensive flats above the true marshes, that in 1914 were open alkaline barrens, in 1915 and 1916 were covered with a luxuriant growth of salt grass. Masses of submerged tule roots to be found downstream several miles below the present living growth attest the former limits of the marsh vegetation. Holes dug to a depth of 2 or 3 feet at various places on the marsh often showed a narrow layer of black soil containing remains of *Scirpus* stems and root bulbs beneath a layer of barren clay 18 or 20 inches thick, indicating an ancient marsh area, long ago entirely killed out and submerged. It is doubtful whether introduced plants from regions where the struggle for existence is less keen would be able to adapt themselves to such frequent shifts and changes in environment.

ANIMAL FOODS.

Though most of the ducks found on the Bear River marshes draw their staple food supply from seeds, tubers, or other vegetable matter, there are certain animal foods in this area that are of sufficient

importance to merit attention. Any of the ducks will turn to animal matter for sustenance when it is readily available and snap up insects or even small minnows that may be accessible, though normally the bulk of their food may be vegetable matter. There are, however, at the mouth of Bear River, a few species belonging to the animal kingdom present in such numbers as to form a food supply upon which some ducks feed to large extent during part of the year. Below the lower end of the marsh, where saline conditions are so pronounced as to prevent vegetable growth, are great quantities of the immature stages of several species of alkali flies (*Ephydra hians*, *E. subopaca*, and *E. gracilis*). The larvæ and pupæ of these insects form great masses in the water and the cast-off pupal cases are washed up in windrows that frequently extend for miles along the shores of the lake. With them in equal numbers, or possibly exceeding them in abundance, are the fairy or brine shrimps (*Artemia fertilis*). These small, almost transparent creatures are so abundant that they form veritable clouds in the water, and these, with the fly larvæ and pupæ, form an important source of food for certain species of ducks and also for various shorebirds.[3] After the summer molt spoonbills, or shovelers, begin to gather in the lower bays, and by September 1 are present in considerable numbers. The flocks continue to increase, until by October 1 it is not unusual to see close banks of these birds 2 miles or more long and from a fourth to half a mile deep. At this time the birds feed largely on the brine shrimps and on alkali-fly larvæ and pupæ. They remain here until finally driven out by the freezing of the fresh-water bays, to which they resort to drink. Usually the shoveler is thin and poor in body, but birds killed here were exceedingly fat, so that while this species ordinarily is considered a mediocre table bird, those killed on the lower bays were good eating.

During October the spoonbills were joined by great flocks of lesser scaup ducks (*Marila affinis*) and later by a considerable number of golden-eyes, or whistlers (*Clangula clangula americana*), and all subsisted largely upon the brine shrimps and the immature alkali flies. These ducks were found regularly only in this part of the bay and it was unusual to see them higher up. Ducks shot in this lower area often were crammed with food, so that when the birds were picked up by the feet brine shrimps and fly larvæ oozed in a slimy mass from their throats. It is hardly necessary to point out the value of these supplies of animal food as an additional attraction to bring wild ducks to this marsh.

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[3] Cf. Wetmore, A., On the Fauna of Great Salt Lake: Amer. Naturalist, vol. 51, pp. 753–755, 1917.

OTHER CONDITIONS AFFECTING WATERFOWL.

AGRICULTURAL OPERATIONS.

It has been said in the foregoing that the supplies of seeds carried over winter in the fruiting heads of the bayonet grass, or tule, are of importance as food for the wild ducks returning from the South in spring. As these seeds are available practically throughout the year they furnish a valuable source of sustenance. The burning of large areas, therefore, to clear the marsh or to induce a fresh clean growth for ranging purposes is to be frowned upon, as it tends to destroy a certain proportion of the available stock of duck food. Many of the seeds are charred and destroyed by the flames, and though a part are not seriously harmed a large proportion of the stock is liable to be washed away and lost during the high water incident to the breaking up of the winter covering of ice in spring, and the subsequent floods due to melting snows in the foothills. While the practice of burning clears the marsh, it also destroys mats and tangles of dead vegetation that in many cases form necessary shelters for the breeding ducks, insuring the successful hiding of their nests and later protecting the young until they are strong enough to venture into the open.

A practice that is almost equally injurious is that of mowing certain areas along the banks of the river and the larger overflows in order to put up wild hay. It is of course unavoidable that many ducks' nests are destroyed in the alfalfa and hay fields in the uplands, as these areas produce valuable crops. Where Bear River breaks up into overflows near its mouth there is a narrow band of sweet clover, salt grass, and foxtail along the banks that is sometimes harvested with mowing machines. Where this is done before July 20, a considerable number of ducks' nests are uncovered or destroyed, and in some cases the ducks themselves are maimed or killed. Nests exposed in the open are in a majority of cases rifled by magpies, coyotes, or other enemies and so are destroyed. The cinnamon teal and gadwall nest commonly in these areas, and in this way are injured frequently. Where mowing is necessary it should be done after July 20, if possible, and in any case the vegetation bordering the channels should be left untouched. Comparatively few of the ducks that nest here locate their nests farther than 100 feet from the water's edge, and by mowing outside this limit only an occasional brood will be destroyed.

NATURAL ENEMIES.

Magpies.—The ducks in the area under consideration are not without natural enemies. Among these the magpie is perhaps the most common, though it is restricted in its range to the immediate vicinity of the narrow band of willows that lines the river bank and

the shores of some of the larger overflows. The depredations of these birds are confined almost entirely to pilfering eggs from the nests, though occasionally they may kill newly hatched ducklings. In a number of places the writer observed ducks' nests that had been broken up by magpies during 1915 and 1916. This was especially the case with nests exposed during haying operations. There is no question that magpies, finding conditions here favorable to their increase, have multiplied to a point where they are directly injurious to other more valuable species. It is a comparatively simple matter to limit their numbers by means of poisoned baits properly used. Under proper conditions one man should be able to reduce them to the desired minimum in two or three weeks' work.[4] It is neither necessary nor profitable to carry poisoning operations far enough to exterminate the birds, but merely to control them to the point of eliminating a large part of the damage.

Gulls.—Ring-billed and California gulls do not appear to harm the ducks during the breeding season, but during the fall kill a good many that are helpless with the duck sickness. Ravens do a certain amount of damage in the same way, but are not common enough to be considered definitely destructive. The case of the gulls is somewhat different, as these birds are abundant and often are present in large flocks. During the shooting season gulls also attack ducks that have been killed by hunters and, not content with eating from one bird, often pick and tear open several, taking only a small portion of flesh from each. From observation it has developed that certain birds may become addicted to this practice, and it is an open question whether these individuals should be killed to prevent such unwarranted destruction.

Other birds.—Among bird enemies that have not been mentioned are the duck hawks, which take occasional toll, and the black-crowned night heron, which at times eats young ducklings. The ducks destroyed by these two are, however, a negligible quantity and do not warrant the persecution of these birds.

Coyotes.—The coyote is another enemy of the ducks and destroys a considerable number each year. In the delta region of the river these mammals occur during the summer, but do not become common until the middle of August or the first of September, at which time their tracks may be found in abundance. They work through the marshes in search of young ducks and "flappers" and also follow the borders of the bays to secure birds suffering from the duck sickness that has come into prominence here during recent years.[5] Many

[4] Those interested may obtain instructions for preparing properly poisoned baits by writing to the Biological Survey, Washington, D. C.

[5] Cf. Wetmore, Alexander, The Duck Sickness in Utah: U. S. Dept. Agr. Bull. 672, pp. 25, pls. 4, 1918.

birds suffering from this malady manage to crawl out of the water and take refuge in the vegetation, where they lie frequently for several days in a more or less helpless condition. Where coyotes are numerous a large proportion of these ducks are captured and eaten. As many of them, if not molested, would recover, considerable destruction is thus wrought by the coyotes. During three seasons' work the writer has seen where several hundred of these sick ducks were killed and eaten by these animals.

Other mammals.—In some parts of the marsh many domestic cats run wild and not only destroy numbers of young ducks, but also, strange as it may seem, a fair proportion of fully grown ones. Haunts of these cats found in the rushes were strewn with ducks' feathers and bones. A few skunks are found on the marshes, but minks are very rare. Some have thought that the porcupines that wander down here from the mountains in fall feed upon birds, but this is entirely without basis, as the porcupine is vegetarian in its feeding habits.

Hogs ranging in the marsh at any season would inevitably cause great damage by destroying nests and young and by rooting out the marsh vegetation. In September, 1916, a drove of hogs made their way down the river to the region at the mouth of Browns Overflow and fed there for several days before they were driven out. At that time there were many sick ducks in this area, and numbers of the helpless birds were lying concealed in the marshy growth lining the shore. General conditions at the time were such that if unmolested a large proportion of these birds would have recovered, but as it happened several hundred ducks were killed and eaten by hogs. This is only an instance of the damage that may result from such invasion, and all measures should be taken to prevent stocking the marsh with hogs. Damage to marsh vegetation by these animals may be seen in the marshes at Locomotive Springs, near Kelton, where large areas of *Scirpus* have been rooted out.

Fish.—Carp have been introduced in Bear River and are enormously abundant in the marsh region in the delta. In summer they frequent the open bays in great droves and do a certain amount of damage by digging out the growths of sago pondweed. The quantity destroyed is not now excessive, but it might easily become so if measures were not taken to keep down the increase of these fish.

CONCLUSION.

During three seasons devoted to field work, eleven species of ducks and the Canada goose were found breeding in the region included in the Bear River marshes. This covers an extensive area in the Salt Lake Valley, Utah, lying in the delta of Bear River and extending inland to the sloughs west of Corinne and below Brigham.

In a conservative enumeration made during May and June, 1916, of the eleven species of breeding ducks, 3,650 pairs were counted, and it is believed that this number represents between 60 and 100 per cent of the total number of breeding ducks occurring there that season. Allowing 5 young reared to maturity as the average for each pair, and considering 1916 as an average season, it may be stated that between 25,000 and 30,000 wild ducks native to the marsh are to be found there at the close of the breeding period.

In addition, a large number of other ducks come in after the nesting season in order to molt, and, after renewing their feathers, to rest in the shelter of the marshes until fall. These nonbreeding birds appear during the first part of June and are present in large numbers by the first of July. They increase through July and August, but during the first week in September a large proportion migrate to other regions. Other ducks continue to come in from the north, however, and by the opening of the hunting season on October 1, a full complement again is present.

Of the duck foods attractive to these birds, two plants, the sago pondweed and the tule, or bayonet grass, both occurring in abundance, furnish a large part of the vegetable portion; in all, 49 plants were found available as duck foods. In addition, the brine shrimp and the immature stages of the alkali flies, both of which swarm in the salt water below the marsh, are relished by certain ducks. Though in other localities it has been possible in many instances to add certain growths to the species already present, the food plants occurring on the Bear River marshes seem to comprise the most valuable of those capable of being propagated under the prevailing alkaline conditions of soil and water. Wild celery might form a useful addition, but its introduction would be in the nature of an experiment.

The practice of burning the marsh in fall and winter destroys the seeds held in the seed heads of the tules, a valuable supply of food available to the ducks when they return to the marsh in spring. Cutting wild hay along the banks of the river and the larger overflows before July 20 lays nests open to attack or may destroy them, together with the brooding birds. This damage would be obviated if haying were begun later, or if a strip at least 100 feet wide were left uncut along the stream banks. These measures should be taken where possible. Among other factors contributing to the destruction of ducks may be mentioned magpies, coyotes, and the domestic cats which run wild on the marsh, and California and ring-billed gulls. The gulls kill many ducks helpless from the duck sickness that otherwise might recover, and in addition are more or less of a nuisance in the shooting season, as they attack and mutilate many ducks that have been killed by hunters.

In general, it may be said that conditions on the Bear River marshes are favorable for the attraction and preservation of a large number of wild ducks. This area may be likened to the lower end of a great funnel, that, drawing its supply of waterfowl from Salt Lake Valley and also from a broad area to the north, concentrates the birds here until they spread in migration to other regions of the West. That these birds do range widely after leaving these marshes has been shown by records of ducks that have been banded and released here and subsequently have been shot elsewhere.[6] Records thus obtained show that birds released near the mouth of Bear River in migration cover the region from Oklahoma and Texas west to the Pacific coast in California.

[6] During an investigation of the duck sickness mentioned as occurring on these marshes, a considerable number of ducks were banded and released. The aluminum bands used are placed securely on the legs of the ducks. These bands are of two types, each bearing a number on one side; the reverse in one style is inscribed "Notify U. S. Dept. Agr., Wash., D. C.," and in the other, "Notify Biological Survey, Washington, D. C." It is hoped that sportsmen killing ducks marked in this way will forward the bands at once as directed, with information as to date and place of capture and any other details that seem relevant. Valuable information is available from such return records as to lines of migration, longevity of individual birds, and other points of value in study of conditions affecting waterfowl.

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Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C. ▼ April 9, 1921

COOPERATIVE GRAIN MARKETING.

A Comparative Study of Methods in the United States and in Canada.

By J. M. Mehl, *Investigator in Cooperative Organization.*

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INTRODUCTION.

The history of underlying causes and conditions surrounding the establishment and growth of a large number of the single-unit type[1] of farmers' elevators in the United States is not radically different from the history of the grain growers' movement in Canada. However, in the actual establishment of marketing facilities, the farmers of Canada pursued a different course. Instead of the locally owned and operated form of farmers' elevators found in the Middle Western States of the United States the Canadians found it desirable to establish centrally controlled elevators of the line-house type. While there are a number of the single-unit type of farmers' elevators in Canada, it is the rather conspicuous success of the line-house type which has attracted attention in this country, and it is these which are usually meant when reference is made to the Canadian plan.

[1] By the single-unit type of farmers' elevators is meant an elevator wherein ownership and control is vested in the body of stockholders in the immediate surrounding community and which is operated as a separate unit independently of any other similar elevator.

The Canadian plan, in the above sense, is typified in two large companies: The United Grain Growers, Ltd., with headquarters at Winnipeg, Manitoba, and the Saskatchewan Cooperative Elevator Company, Ltd., of Regina, Saskatchewan. These two companies own and operate over 600 country elevators in the three Provinces of Alberta, Saskatchewan, and Manitoba, in addition to other activities, which will be more specifically referred to in another part of this bulletin.

Because the Canadian farmers' companies have entered the terminal markets and in other ways have carried their marketing activities further than have the single-unit type of farmers' elevators in the middle western section of the United States, some have thought that the American farmers erred in their scheme of organization and that the Canadian type of organization is the correct type for this country as a whole. It is not the purpose of this bulletin to try to establish which is the correct type, but rather to segregate and distinguish certain conditions and factors relating to the operation of different types of organizations and to assist the reader to a better understanding of cooperative grain marketing as carried on in various parts of the United States and in Canada.

In the collection of material for this study, personal visits were made to typical organizations representing different types and operating conditions, and numerous interviews were held with persons variously engaged in grain marketing in this country and in Canada.

THE FARMERS' ELEVATOR MOVEMENT.

EARLY DEVELOPMENT.

There is a notable difference in the manner in which the cooperative activities of the farmers took concrete form as between the middle western section of the United States and western Canada. In the United States the farmers began by establishing their own cooperatively owned elevators at the local station, trusting to independent commission firms in the terminal markets to furnish an outlet for their grain. The individual grower of grain sold his grain to his own local elevator company, in which he was a stockholder, and it in turn found an outlet for the grain through the regularly established commission firms and other trade avenues. In Canada, on the other hand, the farmers first organized for the purpose of securing legislation favorable to direct shipments by individual growers and of correcting alleged trade abuses. There was no attempt by the growers, in the beginning, to establish elevators; their efforts were directed toward securing the privilege of loading their own grain directly into cars and having it sold fairly in the central markets. That a grower might, if he so desired, ship his grain direct seemed to offer at least a check on those elevators which were unreasonable in their charges

simply because the grain eventually had to move through them. The result of their efforts was the Manitoba Grain Act, which later became the Canada Grain Act. This act is very comprehensive, and it specifically prescribes how nearly every phase of the business of grain marketing in Canada shall be carried on. Among its many provisions are regulations relating to the distribution of cars and the establishment by railroad companies of loading platforms for the convenience of individual shippers. There is also provided a licensing system for country elevators, commission merchants, terminal elevators and track buyers. Under this act comes also the authority for and the establishment and administration of grades, as well as weighing and inspection. The law is administered by a commission appointed by the Governor in Council of Canada.

It was not until extensive investigations by the Government had been made of the entire grain-marketing system at the instance of the grain growers' associations of some of the Provinces, and the passage of the Manitoba Grain Act, that the grain growers in Canada engaged in cooperative marketing, and then they entered the terminal markets without first establishing country elevators. Their first activity was the establishment of the Grain Growers' Grain Co., Ltd., at Winnipeg, now the United Grain Growers, Ltd. During the first years of its existence this company conducted a purely commission business, receiving shipments of grain direct from member growers. It will be seen, therefore, that the farmers of Canada went into the terminal markets even before they established elevators at the country railroad stations, whereas in the United States farmers' elevators were first established locally.

Just why the grain growers in western Canada should begin their actual marketing activities in the terminal markets, while in the United States the farmers' elevator movement originated with the establishment of country elevators, may not at first appear clear. However, it must be remembered that in Canada the efforts of the grain growers to market cooperatively began while the country was still new and sparsely settled. Capital with which to erect elevators at the country points was not readily available. Most of the growers had scarcely enough capital to carry on the business of growing wheat, and in that thinly populated section a capital subscription sufficient to erect a modern grain elevator at each shipping point would have amounted to a considerable per capita cost. The wheat farms were large; farm storage was not so adequately provided as it was in Iowa, Illinois, and other Middle Western States when the movement started there, and consequently the establishment of loading platforms, and the possibility of shipping grain direct, without having it pass through the hands of the country dealers, seemed to the growers the most logical way out of their difficulties.

MARKETING CONDITIONS.

In the actual physical handling of grain the bulk handling method prevails in Canada, as it does in the middle western section of the United States. But in the method of marketing on the part of the individual growers there is a difference in practice. In the Middle Western States the local farmers' elevator is usually confined in its activities to buying and selling the grain of its member-patrons and others, and its principal source of revenue is in the profits made upon resale. Comparatively few growers ship direct to commission firms in the terminal markets, and even the practice of storing grain for farmers by the local elevators is being discouraged. In Canada, on the other hand, the grower has a choice between several methods of marketing his grain.

(1) He may deliver his grain to the local elevator, and sell it at the current price paid by the elevator in the same manner that most of the country grain is sold in the Middle Western States, in which case it is designated as "street grain," and the prices which are paid for grain sold in this manner are called "street prices."

(2) He may have his grain stored in a special bin, the identity of the grain being preserved, and later he may have it loaded into cars for direct shipment. In this case he pays to the elevator company merely its charge for storage and loading. After the grain is loaded into the car, and before it is shipped, he may sell it to the elevator company with which he special-binned it or he may sell it to any other company or track buyer, in which case it is referred to as "track grain," and the prices paid for this kind of grain are called "track prices"; or he may ship to the terminal market, there to be sold on consignment either by the same elevator company, providing it is engaged in the commission business, or by some other commission firm.

(3) He may have his grain placed in store in the local elevator with other grain of like kind and grade, which is called "grade storage," and at some time in the future he may sell it as "street grain"; he may have an equivalent number of bushels loaded into a car, and there sold as "track grain"; or he may ship on his own individual account to the terminal market.

(4) He may load his grain directly into the car, utilizing the loading platforms provided by the railroad companies for that purpose, and sell it as track grain or consign it direct to some commission firm in the terminal market.

(5) If upon arrival in the terminal market of grain shipped for the account of a grower the grower elects not to sell, he may under certain conditions have the car ordered to a public terminal elevator for further storage. Direct shipment privileges, of course, are limited to carload quantities.

For the purpose of catering to those growers who wish to make use of the special-bin privilege it is necessary to provide elevators having a considerable number of small bins. While the Canada Grain Act makes it obligatory upon all licensed elevators to special-bin so long as they have available space, it can readily be seen that elevators having no desire to special-bin may "grade store" in such manner as to have little or no space available for special binning, especially where elevators are constructed with a limited number of large bins only. The farmers' companies claim to provide more special-bin accommodations than the private-owned elevators usually give. In special binning the grower may be required to pay storage on the capacity of the bin which is needed for his special purpose.

In the matter of storage for growers, the elevators in Canada may, upon giving 48 hours' notice to the owner, ship the stored grain from the country elevators to a public elevator, thus relieving congestion at the local elevators.

THE UNITED FARMERS' ASSOCIATIONS.[2]

In Canada the farmers have been fortunate in having only a comparatively few general educational and agricultural associations which are broad in scope and territory, and the result has been concentration of effort along definite lines. In the three principal grain-growing Provinces, Alberta, Saskatchewan, and Manitoba, for example, there are found the United Farmers of Alberta, the Saskatchewan Grain Growers' Association, and the United Farmers of Manitoba, respectively. These and similar associations in some of the other Provinces, together with their respective affiliated commercial organizations, are united in the Canadian Council of Agriculture, and through these various associations practically all of the demands of the agricultural interests in Canada are voiced. There is, therefore, no division of interest or effort among what might be termed competing farmers' organizations, as has sometimes been the case in the United States.

The existing associations are well supported, and there is unity of action. With the exception of the Saskatchewan Grain Growers' Association, these organizations have confined their efforts largely to educational and legislative lines, leaving commercial undertakings to separate and distinct trading corporations. The Saskatchewan Grain Growers' Association is incorporated as a trading company and is engaged in handling all kinds of farm supplies, but inasmuch as its commercial activities are carried on in separate departments, there is in reality a clean-cut division between its educational activities and the handling of supplies.

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[2] Formerly known as the Grain Growers' Associations. They are now more frequently called the United Farmers of a certain Province, as the United Farmers of Alberta.

The principal reason why the Saskatchewan Grain Growers' Association is engaged in commercial activity is that the Saskatchewan Cooperative Elevator Co. deemed it wise to confine its activities strictly to a grain business and there was a demand for certain supplies usually handled in connection with elevators. The trading department of the Saskatchewan Grain Growers' Association was created to satisfy this demand.

The several provincial associations concern themselves with matters of local interest and with legislation to be had through the provincial governments, while the Canadian Council of Agriculture is concerned with matters of national scope. The latter is able to sift and harmonize the various resolutions which come to it for action from the conventions of the provincial associations.

FIG. 1.—View of loading platform and country grain elevators in Saskatchewan, Canada.

It will not be practicable in this bulletin to discuss the various activities of these organizations nor to describe them in detail. They are financed by membership dues and in the past have also received large grants from the earnings of the principal farmers' trading companies, such as the United Grain Growers and the Saskatchewan Cooperative Elevator Co. Each provincial association is composed of locals which have as their center the local shipping station or perhaps the country schoolhouse. These associations are regarded as the power back of everything that has been accomplished by the grain growers in Canada in the matter of establishing their cooperative marketing and trading organizations.

EXAMPLES OF MARKETING ORGANIZATIONS IN CANADA.

The Canadian grain growers first entered upon the commercial handling of their grain in 1906, when the Grain Growers' Grain Co. was established at Winnipeg. For several years this company confined its activities to an exclusive grain commission business, handling the grain of its members in much the same manner as any other commission firm. From the beginning it had a seat on the Winnipeg Grain Exchange and received shipments from member and nonmember growers in the three prairie Provinces. The rules of the Winnipeg Grain Exchange made it impossible for this company to prorate its earnings on the basis of patronage furnished, and while it was at one time suspended because of a supposedly avowed

purpose to so distribute its earnings, it has consistently followed the regular established usages of the grain trade.

In 1911 the Saskatchewan Cooperative Elevator Co., Ltd., was established, with headquarters at Regina, Saskatchewan, and in 1913 the Alberta Farmers' Cooperative Elevator Co., Ltd., with headquarters at Calgary, Alberta, was formed. Each of these companies was successful in building up quickly a large membership and in handling a large volume of business. Both the Saskatchewan Cooperative Elevator Co. and the Alberta Farmers' Cooperative Elevator Co. received financial assistance from the provincial governments, which consisted in an advance by the Government of 85 per cent of the cost of buying or building an elevator, to be repaid in installments extending over a 20-year period.

FIG. 2.—Country elevator of the Saskatchewan Cooperative Elevator Company, Ltd.

In addition to mortgages and preference accruing to the provincial governments in the elevators and assets of these companies as security for the repayment of advances made, the special incorporation acts under which the companies were created, provided, among other things, for audits by a provincial auditor, and also provided that certain conditions relative to acreage and other factors necessary to success must be met before elevators could be built. While giving very wide powers to farmers' companies, the provincial governments also tried to guard them against ill-considered acts by reserving to the Government certain matters for approval.

The Grain Growers' Grain Co., the Saskatchewan Cooperative Elevator Co., and the Alberta Farmers' Cooperative Elevator Co. were all incorporated under special legislative acts.

In 1917 the Grain Growers' Grain Co. and the Alberta Farmers' Cooperative Elevator Co. amalgamated under the name of the United Grain Growers, Ltd., so that at the present time the United Grain Growers, Ltd., and the Saskatchewan Cooperative Elevator Co., Ltd., are the two outstanding examples of farmers' grain-market-

ing organizations in Canada. An analysis of the organization plans and operating methods of these two companies will, therefore, be sufficient to give the reader an idea of cooperative grain marketing as practiced by western Canada.

THE SASKATCHEWAN COOPERATIVE ELEVATOR CO., LTD.

The Saskatchewan Cooperative Elevator Co., Ltd., was formed as the direct result of recommendations made by a commission appointed by the Saskatchewan provincial government in 1910 to investigate and report upon the entire grain situation in western Canada. Prior to the appointment of this commission the grain growers' associations had been pressing the provincial government of Saskatchewan to acquire and operate as public utilities the country elevators in Saskatchewan. The recommendations of the commission were opposed to the proposition to own and operate the country elevators; instead it recommended the incorporation of a farmers' elevator company for that purpose, to be assisted by the government in the matter of financing. Although the recommendation of the commission was not what the farmers of Saskatchewan had hoped for, it proved to be the best course, for about the same time the provincial government of Manitoba was persuaded by the Manitoba Grain Growers' Association (now the United Farmers of Manitoba) to purchase a large number of country elevators and attempt to operate them. The venture was unsuccessful after two seasons and the 170 or more government-owned country elevators in Manitoba were subsequently leased to the Grain Growers' Grain Co. They are under lease to the United Grain Growers, Ltd., at the present time.

The Saskatchewan Cooperative Elevator Co. is incorporated under a special act of the Saskatchewan Legislature. During the first years of its life it established over 40 country elevators and handled more than 3,000,000 bushels of grain. Since that time the number of country elevators operated by it has grown to over 300 and in one year it is said to have handled as much as 43,000,000 bushels of grain. The financial statement of this company for the season 1918–19 shows it to have a paid-up capital stock of $1,122,312.50 and a surplus of $1,969,591.36. Its stockholders number over 21,000. The average number of shares held by a stockholder is slightly more than 3. Par value of shares is $50. During the season 1918–19, which was a short crop year, 20,823,138 bushels were handled through 308 of its country elevators. Grain handled for farmers direct, that is, platform-loaded cars, amounted to 1,018,418 bushels. The company conducts a commission business on the Winnipeg Grain Exchange and operates two terminal elevators at Port Arthur, Ontario. One has a capacity of 650,000 bushels and is suitable for mixing and

conditioning purposes; the other has a capacity of 2,500,000 bushels and is being enlarged to practically double its original capacity. This is used exclusively for public storage purposes.

The affairs of the Saskatchewan Cooperative Elevator Co. are administered by a board of nine directors, each of whom holds office for three years. In the election of these directors the stockholders do not have a direct vote, but each local, at least 30 days prior to the annual meeting, elects a delegate to represent all of the stockholders within such local. This delegate has one vote only, regardless of the number of stockholders in a given local.

The locals are established in this manner: Whenever a group of farmers desire an elevator at their shipping point, to be operated as a unit of the Saskatchewan Cooperative Elevator Co.'s system, they may petition the company to establish a local. Under the provisions of the Saskatchewan Cooperative Elevator Act the directors may not, without the consent of the Lieutenant Governor in Council, establish any local unless it appears to their satisfaction that the amount of shares held by the supporters of the proposed local is at least equal to the value of the proposed elevator, that 15 per cent of the amount of such shares has been paid up, and that the aggregate annual crop acreage of the said shareholders represents a proportion of not less than 2,000 acres for each 10,000 bushels of elevator capacity asked for. Upon the establishment of a local the supporting shareholders meet and elect a local board of management consisting of five members, who hold office until their successors are appointed. Each stockholder may own not more than 20 shares of the stock of the company ($1,000) and has only one vote, regardless of the number of shares owned. At this meeting of the supporters of a local there is elected the delegate who represents all of the stockholders in that local at all the general meetings of the company.

While the local board of management has no powers or authority not delegated to it by the general board of directors of the company, it does, nevertheless, perform a valuable service in advising the general directors with respect to matters of local concern. The directors in the local do not actually control even the manager or agent of their own local elevator, but their recommendations relative to such matters are necessarily given weighty consideration by the general board. They also are able to bring to the attention of the general board any dissatisfaction existing among the local members and to suggest improvement in the service. The price to be paid for grain at a local elevator, of course, is determined exclusively by the central office, and all matters of business policy are dictated from this office. The duties of the local agent are confined mainly to carrying out the instructions of the central office and reporting to it regularly and in detail the business transacted by him.

Section 20 of the act to incorporate the Saskatchewan Cooperative Elevator Co., Ltd., stipulates the manner of apportioning earnings. In substance it provides that after expense of operation and certain charges have been paid, including the payment of installments and interest of loans due the Government, out of the remaining earnings may be paid a dividend not to exceed 10 per cent upon the paid-up capital; 50 per cent of the balance, if any, may then be distributed in several different ways:

(1) It may be paid to the shareholders in the form of a patronage dividend, proportionate to the volume of business which each has brought to the company. Under this method the earnings of the company are considered as a whole, no account being taken of the variable net profits accruing from the different locals.

(2) It may be paid to the supporters of the locals on the basis of the aggregate relative net financial results of the respective locals. This method recognizes the differences in operating cost at the different locals and provides a means whereby the supporters of less profitable locals may be precluded from sharing fully in the profits of locals which have been better supported.

(3) It may be paid partly according to each of the above-described methods. In this case the supporters of a particular local may share less fully in the earnings which are peculiar to that local than they would under method 2.

(4) It may be applied on the unpaid portion of shares; that is, a certain amount may be placed to the credit of the shareholders for each share held but not fully paid up, thereby lessening the unpaid portion and increasing the paid-up capital stock of the company.

The remaining 50 per cent of the balance may be set apart as a reserve under what has been designated in the act of incorporation as "the elevator reserve account."

While patronage dividends may be paid the members of the Saskatchewan Cooperative Elevator Co. to the extent of 50 per cent of the net profits remaining after certain other payments have been met, including a dividend on capital stock, no such patronage dividends have ever been paid. Under a rule of the Winnipeg Grain Exchange forbidding rebates, the payment of patronage dividends has been regarded as a form of rebates subjecting the member to suspension, and this is one reason that patronage dividends have not been paid. There is some sentiment for patronage dividends, but so far the directors of the company have felt the need of all earnings which have accrued and have employed them in the further expansion of the business.

Up to the present time the Saskatchewan Cooperative Elevator Co. has confined its activities to the handling of grain exclusively and has not engaged in handling supplies of any kind.

THE UNITED GRAIN GROWERS, LTD.

The Grain Growers' Grain Co., organized in 1906, first operated under a Manitoba provincial charter. In 1911 it applied for and received a charter from the Dominion Government. The Alberta Farmers' Cooperative Elevator Co., organized in 1913, operated under a charter of the Alberta provincial government until 1917, when it amalgamated with the Grain Growers' Grain Co. and the two companies became the United Grain Growers, Ltd., by amendment to the Grain Growers' Grain Co.'s Dominion charter. At the time of the amalgamation the Grain Growers' Grain Co. had a paid-up capital stock of $1,357,382.46 and a surplus of $1,118,351.51, while the Alberta Farmers' Cooperative Elevator Co. had a paid-up capital stock of $563,689 and a surplus of $541,004.38. On August 31, 1919, the paid-up capital stock of the new company, the United Grain Growers, Ltd., was $2,415,185.58 and the surplus $1,756,429.78. The authorized capital stock of the new company was placed at $5,000,000, divided into 200,000 shares at $25 each. Because of the accumulation of a large surplus, tending to increase the real value of the shares, the selling price is fixed at $30 per share. Each member may own not more than 100 shares, and membership is limited to the owners or lessees of farm land or their wives, unless, by special resolutions of the members, others are admitted. Over 35,000 shareholders compose the present membership of the United Grain Growers, Ltd., and these are divided into locals as in the case of the Saskatchewan Farmers' Cooperative Elevator Co. To form a local 40 members are required, holding at least 267 shares. Each local elects a local board of 5 members, who act mainly in an advisory capacity to the general board of directors. The local also elects one delegate to represent the supporting shareholders at the general meetings of the company. Each delegate has only 1 vote, regardless of the number of shareholders belonging to a single local, but in case a local has 188 or more members it is entitled to have 2 delegates. In the meetings of the locals each shareholder has only 1 vote, and voting by proxy is not allowed either in the general meetings or in the local meetings. The affairs of the company are administered by a board of 12 directors, 4 of whom are elected each year to serve for a period of three years.

A by-law provision gives full authority to the board of directors to determine the basis of the distribution of earnings. No patronage dividends have been paid.

In the operation of its country elevators much the same methods are used by the United Grain Growers as are used by the Saskatchewan Cooperative Elevator Co. Management is centralized in the office at Winnipeg, but the office organization of the old Alberta

Farmers' Cooperative Elevator Co. is being maintained at Calgary, Alberta, as western division, and through it is administered all of the business affecting the local elevators in Alberta, while the Winnipeg office has direct contact with the elevators in Manitoba and Saskatchewan.

While the Saskatchewan Cooperative Elevator Co. has consistently adhered to its policy of handling grain exclusively, the United Grain Growers, Ltd., has engaged in numerous other operations. In addition to operating terminal elevators at Fort William and Port Arthur, Ontario, and conducting departments for handling farm supplies of all kinds and for live stock, it controls a number of subsidiary corporations. Among these may be mentioned the Grain Growers' Export Company, Inc., of New York; the Grain Growers' Export Co., Ltd., of Canada; Public Press, Ltd., Winnipeg; the Grain Growers' Guide, Winnipeg; United Grain Growers' Securities Co., Ltd., Calgary; United Grain Growers (British Columbia), Ltd., Vancouver; United Grain Growers' Sawmills, Ltd., Hutton Mills, British Columbia. The first two companies were organized to enable the parent organization to conduct to better advantage the export business, which was begun as early as 1910. Through the Public Press, Ltd., and the Grain Growers' Guide, Ltd., is carried on the business of publishing the Grain Growers' Guide, a weekly publication devoted especially to agricultural interests in Canada. The United Grain Growers' Securities Co., Ltd., is engaged in conducting a general insurance business and a land department. The United Grain Growers (British Columbia) was formed for the purpose of furnishing a western outlet for grain for feed purposes, and the United Grain Growers' Sawmills, Ltd., was intended to provide manufactured products from a timber tract purchased in British Columbia in 1912. All of the subsidiary companies are owned and controlled absolutely by the United Grain Growers, Ltd., and the affairs of each are administered by the directors of the controlling company.

The annual report of the United Grain Growers, Ltd., for the year ending August 31, 1919, indicates a volume of business in farm supplies of $6,180,359. Among the items handled are flour and feed, coal, hay, posts, twine, wire and bale ties, salt, fruit and vegetables, lumber and builders' supplies, machinery and supply parts, sacks, trucks, oils, and miscellaneous articles. During the year the company handled 22,203,007 bushels of all kinds of grain, which is considerably less than it has handled in former years. The live-stock department handled a total of 5,257 cars.

TERMINAL ELEVATORS.

Both the United Grain Growers, Ltd., and the Saskatchewan Cooperative Elevator Co., Ltd., have public and private terminal ele-

vators located either at Port Arthur or Fort William, Ontario, from which grain may move eastward by rail or boat across the Great Lakes. By public terminal elevators is meant terminal elevators which have qualified as such under the Canada Grain Act and are duly licensed to conduct a public storage business under the rules and regulations prescribed by the Board of Grain Commissioners for Canada.

A distinction should be noted here between public terminal elevators and private terminal elevators. The former are not allowed to mix grades nor to own any of the grain held in their custody as public warehousemen. Their business is to clean and store grain under such conditions and for such charges as the Board of Grain Commissioners for Canada may approve. They are subject to very close Government supervision, and warehouse receipts issued by them are deliverable on future contracts. The private or "hospital"[3] elevators, while also under Government supervision, are allowed to mix certain grades, but are not allowed to conduct a public-storage business. They must buy all of the grain which they handle. They, of course, are able to earn a considerable amount at times through their mixing operations. For example, when low-grade grain is being sold at heavy discounts they may buy a quantity of very high quality No. 2 Hard wheat, mix into it a quantity of low-grade wheat and still retain No. 2 grade. It may be noted that hospital elevators are prohibited from taking certain grades into their elevators and also that when it appears that grain shipped from any private elevator is being systematically reduced in quality below the general average quality of the grain of similar grades in the bins of the public terminal elevators, such grain may be required to pass inspection at a lower designated grade. It will be seen therefore, that while the manufacturing of grades by mixing constitutes a considerable part of the business of private elevators, even these operations are not without limitation.

The benefits which may be secured to the farmers' companies from the operation of hospital elevators are evident. These elevators enable them to condition their own grain and to take advantage of any profits to be made through mixing operations. In the operation of their public terminal elevators, however, the source of profit is somewhat obscured by the fact that under the law they may not store any grain for themselves, but must depend for their profits upon storage patronage secured from others.

The methods by which grain is sold on the Winnipeg Grain Exchange is of interest in this connection. While sample markets have

[3] The Canada Grain Act defines a hospital elevator to include every elevator or warehouse which is used for cleaning or other special treatment of rejected grain which is equipped with special machinery for that purpose.

recently been provided for in Canada, the great bulk of the grain business in the past has been conducted on the basis of Government inspection and grade. Sales are made by grade and without examination of samples. Grain bought in the country may be sold either in transit before inspection, after inspection but before being unloaded, or after being unloaded and placed in public storage. A large share of all the grain marketed in Canada is understood to be sold on basis in store at Port Arthur or Fort William. In actual practice one of the farmers' companies operating public terminal elevators may consign grain which it has bought at country stations to its own terminal elevators at Port Arthur or Fort William but before the car is unloaded the grain is sold to shipper or exporter. If in the meantime the car is not diverted or ordered to some other elevator, the farmers' company will in natural course receive this storage patronage. In addition to patronage secured in this way there is more or less opportunity to exchange warehouse receipts with other companies operating terminal elevators.

For example, the Saskatchewan Cooperative Elevator Co. is not allowed to own any of the grain which it has in its public elevators, but it may own grain stored in the public elevators operated by the United Grain Growers or any other company. It is a simple matter to transfer title to grain held in one elevator for title to grain held in another elevator by the indorsement of warehouse receipts. In this manner one public elevator may give storage patronage to another elevator in return for similar storage patronage received. The practical results are the same as if a public terminal elevator were allowed to have custody of the grain owned by it, with this exception, that there is less temptation to substitute or to specially select grain taken out of storage for delivery on contracts in which the company is directly interested. Under the present system of elevator supervision, however, there would be very little opportunity for practices of this kind.

Since public elevators are required to account for every bushel of grain received by them and are made responsible for shortages, they have likewise been deemed to be entitled to overages. Grain received into these elevators has been government-inspected and warehouse receipts are issued for the net number of bushels after deducting dockage. No matter how accurate may be the method of ascertaining the percentage of dockage in any one lot, discrepancies in cleaning are bound to occur. A very small percentage variation in dockage amounts to considerable in handling several million bushels. While every effort is made to keep overages down to a minimum without resulting in shortages and while shortages do occur sometimes, nevertheless the records indicate that overages are not uncommon and a possible additional revenue is had from this source.

No figures are available to show what proportion of the grain received into public storage in the large terminal elevators at Port Arthur and Fort William is owned by individual growers, but it is not large. However, it will be seen that in the case of the farmers' companies any public storage business conducted for the members is reflected in earnings in which the members have a direct interest. In addition to the direct financial benefits which accrue to the grain growers in Canada from the operation by farmers' companies of terminal elevators, certain indirect benefits are also claimed as the result of the restraining influence of farmers' competition on others engaged in the terminal elevator business.

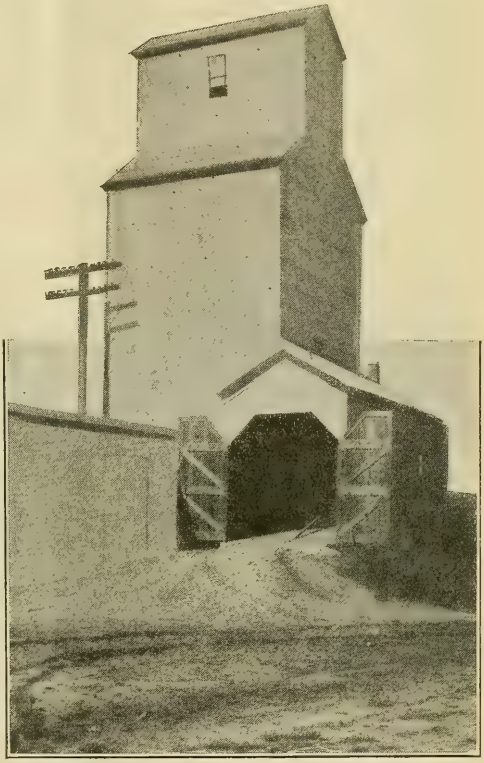

FIG. 3.—Typical farmers' elevator of the local single-unit type found in middle-western section of the United States.

EXAMPLES OF FARMERS' ORGANIZATIONS IN THE UNITED STATES.

LOCAL FARMERS' ELEVATORS.

By far the most of the farmers' elevators in the United States are of the single-unit type. The growers surrounding a shipping point will raise the necessary capital to build or buy an elevator. A corporation will be formed, a manager hired, and the business of buying and selling grain will be conducted independently of any other farmers' elevator or marketing organization. A farmers' elevator at one point may be a tremendous success, while at the next station one will fail miserably. In some cases, it is true, several elevators have been combined under one management, and not infrequently a farmers' elevator company located at one point will operate elevators at one or more neighboring points. In Kansas and possibly several other States organizations have been established on what is called the county-unit plan, the idea being to place all the farmers' elevators within a county under one management. The ad-

vantages claimed for this plan are that all elevators within the county may have the benefits of a highly skilled manager which the individual companies could not afford to employ singly, and that there is a decreased general and overhead expense by reason of standardization and centralization of accounting work. In addition, of course, there is a greatly increased purchase power when it comes to buying supplies and side lines usually handled by farmers' elevators. In the main, however, farmers' elevators in this country, and especially in the Middle West, have grown out of local effort, and up to the present time little has been done in the way of federating the individual companies into central organizations for marketing purposes.

The existence of such a large number of the single-unit type of farmers' elevators, the great majority of which have been in successful operation long enough to justify a belief in their permanence as an

FIG. 4.—Typical flat warehouse in sack-handling section of the Pacific Northwest.

economic thing, has naturally raised the question whether cooperative grain marketing should end with these local elevators or whether it should be extended to the terminal markets. No great movement like the farmers' elevator movement can proceed suddenly and rapidly to a certain point of perfection and as suddenly stop and remain stationary. It is true that much remains to be done in the matter of securing a firm footing upon the ground already covered and that stability should be secured there before proceeding further. However, it is also true that if perfection is to be attained in the operation of the country elevators before looking toward the next step, there probably will be no next step, unless, indeed, it be a step backward. That complete success in the operation of local farmers' elevators will be aided by greater unity and community of action is readily apparent, and unity naturally centers around terminal marketing. It may or may not be to the financial advantage of the grain

growers of the Middle West to follow the marketing of their grain beyond the local railroad station. Certainly the advantage will not be so great as it is commonly expected to be by those who view terminal marketing from a distance. But the conviction is general among the grain growers that some advantage is to be had, and it is doubtful whether anything but actual experience can affect that conviction. The problem, therefore, is not to discourage what is a legitimate and proper activity on the part of the grain growers, if they wish to engage in it, but rather to aid in the discovery of means and methods which will make intelligent and constructive effort possible.

FIG. 5.—Bulk-handling elevator in the Pacific Northwest.

TERMINAL ACTIVITIES.

To persons who have been inclined to view the Canadian methods of cooperative grain marketing as something which should be adopted immediately by the grain growers of this country, it may be interesting to know that within our own borders at the present time are at least three organizations which resemble in character the organizations of western Canada. It is true that none has yet approached in size either of the two large Canadian companies, but the idea of centralized management and the operation of local farmers' elevators as a line-house system in connection with terminal activities is not new in this country.

The Equity Cooperative Exchange of St. Paul, Minn., reports about 80 country elevators in operation as part of a line-house system. This company was first organized as a department of the American Society of Equity in 1908, and was incorporated under the laws of North Dakota in 1911. The local elevators of the Equity Cooperative Exchange are controlled absolutely by the general exchange directors, but, like Canadian companies, provision is made for a local advisory board. In addition to country elevators owned and operated as a part of the exchange system, there are a number of the locally owned and operated type of farmers' elevators which own shares of the capital stock of the exchange. These, of course, are operated as free agencies and may or may not favor the exchange with their grain shipments. The exchange operates a terminal elevator at St.

Paul, Minn., but instead of operating on the Minneapolis grain exchange (the Minneapolis Chamber of Commerce), it has established a market place in St. Paul.

The Montana Grain Growers of Great Falls, Mont., organized in 1918 under the laws of Montana, is another organization which in many ways has sought to emulate the Canadian companies. It has now about 20 country elevators under its control with approximately 3,000 members.

In the Pacific Northwest the Tri-State Terminal Co. of Seattle, Wash., furnishes another example of line-house operation of farmers' elevators. This company was formed in 1911. The annual statement of the company for the year ending May 31, 1919, shows a paid-up capital stock of $271,920 and a surplus of $34,302.75. It has a membership of about 2,500, in addition to a number of local farmers' elevator companies owning shares of its capital stock. Over 20 country elevators are operated by it as a part of the line-house system.

Among other organizations which serve or are preparing to serve the interests of farmers' elevators in the terminal markets are the Farmers' Commission Co. of Hutchinson, Kans.; the Farmers' Elevators Commission of Minneapolis, Minn.; the Farmers' Terminal Elevator Co. of Sioux City, Iowa; the National Cooperative Co. of Omaha, Nebr.; the Equity Union Grain Co. of Kansas City, Mo.; and the Michigan State Farm Bureau Elevator Exchange of Lansing, Mich.

FUNCTIONS OF COOPERATIVE GRAIN MARKETING ORGANIZATIONS.

In the case of farmers' elevators of all types in this country and in Canada there has been no material difference in their methods of operation as distinguished from the methods of private interests, except, of course, with respect to policies growing out of ownership of the marketing facilities by a large number of actual grain growers. No attempt has been made to secure control over crops of members, but each grower member has been left free to dispose of his crop when and to whom he chose. The whole effort in regard to cooperative marketing has been directed toward having the grower perform for himself certain functions of marketing which previously had been performed by others, but using exactly the same kind of marketing machinery. The only change is the substitution of cooperative ownership of middleman facilities for private ownership. If the idea of capital stock ownership by growers who are also patrons of the elevator company and the plan of distributing earnings among the members on the basis of patronage furnished were eliminated there would be nothing to distinguish the present day farmers' elevator company from any other corporation engaged in the grain business.

Grain is bought from members and nonmembers alike on the basis of prevailing market prices. Sometimes profits are made much in excess of the margins which were expected at the time of the purchase, and again large losses are similarly suffered. No attempt has been made to market grain by means of pools extending over certain periods and returns made to growers on the basis of average prices received for grain of like variety and grade of a given pool, as has been so successfully done in the marketing of certain perishable and semiperishable products. An exception to this statement may have to be made if an experiment now under way in the Pacific Northwest is successful. The Pacific Northwest Wheat Growers' Associations have recently been organized there. The purpose of these associations is collective bargaining in the sale of wheat under much the same plan that certain California products are now marketed.

Each grower upon becoming a member of the association will sign a contract by which he agrees to surrender control over the marketing of his crop for a period of years. His wheat must be delivered to certain warehouses or shipping points, as ordered by the association. The price to be paid for the wheat will not be known definitely until all of the wheat of a particular kind and grade pooled during the season has been sold. It is expected that by means of a comprehensive warehousing scheme money may be borrowed upon warehouse receipts in liberal amounts and that advances may be made to the grower at the time of delivering his wheat. Also, as wheat in certain pools is being sold and returns received, further advances will be made to growers having wheat in that pool. The principle upon which rests the entire plan, of course, is that an expert in the marketing of wheat will, over a period of years, be able to market the wheat of the grower at a price averaging higher than the individual could obtain for himself with his comparatively little knowledge of world conditions affecting wheat prices. It is also expected that if a considerable proportion of the wheat production in the Pacific Northwest area is secured under contracts of this kind, the manager or selling agent will become an important factor in that market.

At this time it is impossible to judge the ultimate success of pooling as applied to grain. No doubt if there is merit in the plan no better field for demonstrating it is to be found than in the Pacific Northwest, where country warehousing is still the principal function of many farmers' elevators, whereas in the Middle Western States the tendency has been away from the practice of storing grain for farmers. In the States of Oregon, Washington, and Idaho considerable grain is still handled in sacks, piled in flat warehouses, from which it is sold by growers to mills and brokers direct by indorsement of warehouse receipts.

COMPARISONS AND CONCLUSIONS.

One can not carry his investigations of cooperative grain marketing far without realizing that what may be an excellent method for some sections and for some conditions will not always work out successfully in other sections or when applied to other conditions. One hears altogether too much of plans and systems and not enough of analysis of existing conditions. The farmers' elevators of the Middle West are endeavoring to coordinate their activities and to extend their operations to terminal marketing, but it is doubtful if there will be adopted either a Canadian plan or a plan which has been discovered in some other section. The extension of their activities will necessarily be a development along lines that have a special fitness for their own peculiar needs and requirements.

The Canadian system of line-house operation of farmers' elevators would seem to offer greatest advantage in those States where crops are somewhat uncertain or where the crop year is of short duration, some elevators being closed for certain periods each year, and under which conditions it is difficult to secure the type of manager which is necessary if the local company shall market on its own initiative and responsibility. Most managers who are competent to fill an executive position do not care to take a position in a section of the country where short crops may require that they seek other employment during the periods when it is necessary to close the elevator. On the other hand, the type of man who is capable of assuming responsibility and who has the ability to manage a business in all its details will not be satisfied to hold a position where all of the executive and administrative matters are handled from a central office. Of course, there are exceptions.

On the whole, the local agents of the line-house type of farmers' elevators are of exceptionally high grade, but necessarily they are of a different type from the men who are managing the more successful single-unit type of farmers' elevators in Illinois, Iowa, Nebraska, and other Middle Western States.

Another point of difference that needs to be considered is that in Canada the city of Winnipeg is the natural gateway through which passes each year a very large proportion of all the marketed grain of western Canada. It is quite natural for terminal marketing activities to center there. In the United States, on the other hand, are several large terminal markets, among which there is a constant shift of the grain movement from several States.

A central control over the farmers' elevators located in western Iowa, for example, might, during a single year, be logically situated in several different markets. While this condition might be overcome to some extent by the establishment of agencies in each of the

more important markets, it can readily be seen that conditions in this section of the United States may not yield to the same kind of marketing methods that are found desirable in other sections of the United States and in Canada.

The line-house method of operating country elevators has a number of economical advantages over the single-unit type of farmers' elevator which may not be overlooked. For example, it allows standardized construction and machinery. Thus certain repair parts may be kept in stock at a central point, from which they may be shipped quickly where needed. In case of crop failure in restricted areas because of hail or drought which has not affected other sections, it is possible to close the elevators in the affected area during the emergency. Also, elevators may be closed during the dull periods without the losses which are attendant to the single-unit elevator under similar conditions. The advantage of centralized accounting and the opportunity for departmentalization and specialization is apparent.

Favoring the local single-unit form of cooperative elevators is a degree of community pride which usually centers around these organizations, quite independent of the services rendered. Local government carries a special appeal to the average American citizen. This to some extent must be lessened, if not entirely lost, where control is vested in a body of directors and a management distantly situated. In many sections there is a prejudice against centralized authority which is not easily overcome.

In cooperative marketing it is more essential that the system be suited to local conditions and practical need than it is that the system itself shall have been successfully applied in other fields. The local farmers' elevators, typical of the middle western section of the United States, were established primarily to solve marketing problems of local character. That they have not extended their activities to the terminal markets does not in any way reflect upon their success as marketing institutions. Rather it indicates a conservativeness too often lacking in movements of this kind.

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L. O. HOWARD, Chief

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EFFECTS OF NICOTINE SULPHATE AS AN OVICIDE AND LARVICIDE ON THE CODLING MOTH AND THREE OTHER INSECTS.

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INTRODUCTION.

For several years nicotine and its compounds have been used against certain soft-bodied insects as contact insecticides, and within the past few years the question has been raised concerning the effects of nicotine sulphate upon the eggs and early instars of other insects which are commonly controlled by other means.

During 1915 and 1916, in the State of Washington, De Sellem (*1*)[2] carried on field experiments with nicotine sulphate and arsenate of lead and claimed that the former insecticide was as efficient as the latter one for controlling the codling moth (*Laspeyresia pomonella* L.). During the season of 1917 similar experiments in three orchards were performed by the same author and others (*2*) on a larger scale in the same State, and the results obtained showed that nicotine

[1] Resigned March 31, 1920.
[2] Numbers (italic) in parentheses refer to "Literature cited," p. 18.

sulphate did not control the codling moth as well as did lead arsenate, and that its control was unsatisfactory on all of the plats sprayed, except one. The Bureau of Entomology also conducted some field experiments during the season of 1917 in three important apple regions in the United States, the first of these being in the Lake region at Benton Harbor, Mich.; the second one in the mountainous region at Grand Junction, Colo.; and the third one in the semiarid region at Roswell, N. Mex. In the first region the experiments were carried on by Mr. Simanton; in the second one by Mr. Plank; and in the third one by Mr. Fiske. All of the laboratory experiments were performed by Dr. McIndoo.

Lovett (*5*) reports that nicotine sulphate with soap is an effective ovicide for the codling moth. Excepting this experiment, in which only 26 codling-moth eggs were used, no other experiments, either in orchards or in a laboratory, have ever been conducted to determine how nicotine sulphate checks the work of the codling moth, although Feytaud (*3*), testing the effects of pure nicotine and soap in the laboratory upon the eggs of two moths belonging to the same family, ascertained that about 75 per cent of the embryos in the eggs tested were aborted during the last stage of development, while the remaining eggs hatched.

The first portion of the present paper embodies the results obtained in the laboratory concerning the effects of nicotine sulphate as an ovicide and larvicide on the codling moth and three other insects. The second portion of this study deals with the effectiveness of nicotine sulphate as compared with the efficiency of arsenate of lead for controlling the codling moth in orchards.

EXPERIMENTS CONDUCTED IN THE LABORATORY.

In order to throw some light on how nicotine sulphate checks the work of the codling moth the following tests were performed:

EFFECTS OF NICOTINE SULPHATE[3] ON EGGS AND NEWLY HATCHED LARVÆ OF THE SILKWORM MOTH.

This investigation was begun in September, 1916, when it was too late to obtain codling-moth eggs or fresh eggs of any other insect; so the study was begun by using eggs of the silkworm moth (*Bombyx mori* L.), 10,000 of which were 14 months old, 2,000 of which were from 1 to 6 days old, and 10,000 of which were 3 months old.

EFFECTS OF NICOTINE SULPHATE ON EGGS OF THE SILKWORM MOTH.

The eggs just enumerated were divided into several lots, and some of these lots were sprayed with nicotine sulphate (1:800 + fish-oil

[3] Throughout this paper reference is made to "nicotine sulphate" containing 40 per cent of nicotine.

soap, 2 pounds to 100 gallons of water); some with nicotine sulphate 1:800; some with nicotine sulphate 1:1,066; and others were not sprayed, these being used as controls. During October, 1916, all of the eggs 14 months old hatched, but the hatching of the sprayed ones was more or less retarded. Relative to the eggs from 1 to 6 days old when treated, the following data were obtained during the spring of 1917. Only 1 per cent of those sprayed with nicotine sulphate 1:800 hatched, while 80 per cent of the unsprayed ones hatched; in regard to the eggs 3 months old, 20 per cent of those sprayed with nicotine sulphate 1:800+soap hatched, 25 per cent of those sprayed with nicotine sulphate 1:800 hatched; 35 per cent of those sprayed with nicotine sulphate 1:1,066 hatched; while 90 per cent of those unsprayed hatched. The unsprayed eggs hatched quickly, and the newly hatched larvæ grew normally, while the sprayed eggs were more or less retarded in hatching and the young larvæ were so stunted that after 20 days the larvæ from the unsprayed eggs were from 1 to 6 times as large as those from the sprayed eggs. A large percentage of the unhatched eggs contained embryos aborted during the last stage of development.

EFFECTS OF NICOTINE ON NEWLY HATCHED SILKWORMS.

McIndoo (*6, p. 97*) has already shown that the exhalation (called odor) from leaves an hour after having been sprayed with a solution of nicotine sulphate kills small fall webworms (*Hyphantria cunea* Dru.), small caterpillars of the catalpa sphinx (*Ceratomia catalpae* Bdv.), and certain aphids (*Aphis populifoliae* Davis).

On May 12 at 12.30 p. m. a bunch of leaves on a mulberry tree was dipped into a solution of nicotine sulphate 1:400 and another bunch into a solution 1:800. On May 14 at 9.30 a. m. a leaf was removed from each bunch of the leaves treated, and 20 silkworms 1 day old were placed on each leaf; at 12.30 p. m. all the worms were dead. The leaves still emitted a faint odor like that from the solution. On May 16 at 11.15 a. m. the preceding experiment was repeated; on May 17 at 9 a. m. 8 worms on the leaf treated with the solution 1:400 and 1 on the other leaf were dead; all of the remaining live worms were more or less stupid, and two hours later, after having been fed with a fresh leaf treated with the solution 1:400, died. This leaf was cut into small pieces, and it still emitted a very faint odor like that from the solution, but the leaves treated with the solution 1:800 had ceased to emit this odor so far as the observer could perceive. At no time during any of the preceding experiments did the silkworms eat the treated leaves; the exhalation arising from them therefore must have killed the worms.

EFFECTS OF NICOTINE SULPHATE ON EGGS AND NEWLY HATCHED LARVÆ OF THE CODLING MOTH.

In tests with the eggs and newly hatched larvæ of the silkworm moth it was determined that nicotine sulphate is efficient against only the fresh eggs, but more or less retards the hatching of older eggs. The exhalation from leaves which had been dipped into solutions of nicotine sulphate from 1 to 5 days previously killed newly hatched silkworms, and from the sixth to the eleventh day after the foliage had been treated the newly hatched silkworms, after having eaten some of these treated leaves, died, the mortality varying from a high percentage on the sixth day to no mortality on the tenth and eleventh days. The following pages give the results obtained by using the eggs and newly hatched larvæ of the codling moth:

EFFECTS OF NICOTINE SULPHATE ON EGGS OF THE CODLING MOTH IN THE LABORATORY.

Many codling-moth sticks containing wintering larvæ, reared at the bureau's field station in Grand Junction, Colo., were shipped to Washington, D. C., where they were kept out of doors until March 1, 1917; after this date they were kept in a refrigerator, and at irregular periods about 40 of them at a time were removed from the refrigerator and were placed in battery jars, which were covered with cheesecloth. Each morning the moths that had emerged were removed to other battery jars containing moist sand and either glass plates or foliage of fruit trees. In these jars the moths copulated and the females laid their eggs on the glass plates and foliage, which after being removed were then sprayed. By this method eggs of a known age were easily obtained.

Since these experiments were started in March, when fruit-tree foliage was not to be had, glass plates were put in the battery jars, and whenever a sufficient number of eggs had been deposited on these plates, the latter were removed, sprayed, and then placed in other battery jars also containing moist sand.

Since the details of the four experiments performed, using eggs on glass plates, are similar, only Experiment No. 1 will be described fully. On April 4 the first plate, bearing 57 eggs (1 and 2 days old), was sprayed with a solution of nicotine sulphate 1:400; the second plate, bearing 20 eggs, with a solution 1:800; and a third plate, bearing 16 eggs, was used as a control. Each plate was put in a separate battery jar. On April 7 most of the eggs were in the red-ring stage; the sprayed plates bore spots or a thin film as a residue left after the evaporation of the solution, and these spots still emitted a nicotine-like odor. On April 11 many of the eggs were in the black-spot stage and the plates still emitted the nicotine-like odor; two small last year's apples were put in each jar. On

April 12 the eggs on each plate began to hatch, and later when examined 42.1 per cent of those on the first plate had hatched; 60 per cent of those on the second plate and 92.7 per cent of those not sprayed had hatched. On April 13 several dead larvæ were found on the sprayed plates and on the apples by these plates, but no dead ones were found in the jar containing the control plate, and four burrows were counted in the apple by this plate. On later dates it was common to see dead larvæ in each of the first two jars. On April 23 the plate sprayed with the solution 1:400 still emitted a faint nicotine-like odor. The apples by this plate showed four burrows, from which finally emerged two full-grown larvæ; those by the other sprayed plate only one burrow, from which emerged a larva; and those by the control plate also four burrows, from which emerged two large larvæ. Four of the five larvæ passed through the pupal stage and emerged as adult moths, while the fifth one only reached the pupal stage; this one was from the first two apples mentioned.

The preceding tests indicate that nicotine sulphate is not an efficient ovicide against the codling moth when the eggs are laid on glass plates. Other experiments were performed by constantly keeping fresh foliage of pear and apple trees in the battery jars. On the third day after applying the spray solution a nicotine-like odor was still emitted from the leaves, the strength of which depended upon the strength of the solution used. This odor gradually disappeared, and by the time the eggs began to hatch the observer could not perceive it. Unsprayed leaves usually have bright and shiny surfaces, but sprayed ones have dull surfaces, and with the aid of a hand lens a dried film of residue from the solution may often be seen on them. These experiments are summarized in Table I; experiments 1, 2, and 3 represent individual tests with eggs on pear-tree leaves, while experiment 4 is a summary of several tests with eggs on apple-tree leaves. Soap was used at the rate of 2 pounds per 100 gallons of water.

Relative to experiment 4, the following notes, although not significant, are nevertheless interesting. Four last year's apples, each being dipped into the same spray solution as that sprayed on the leaves, were placed in four jars containing the sprayed leaves. Two apples not sprayed were also placed in two jars containing unsprayed leaves. Eliminating one of the four jars and its contents on account of the apple in it becoming badly decayed before the eggs hatched, 245 eggs in the other three jars hatched and later 14 burrows were counted in the three remaining apples. In the two jars used as controls 52 eggs hatched, and later 14 burrows were also counted in the two apples contained therein. Soon after this date all of these apples totally decayed and consequently no matured larvæ were obtained from them.

Three apples, after having been dipped into a solution of nicotine sulphate 1:400+soap, were placed in three battery jars containing many unsprayed eggs. A later examination showed that 49 eggs had been deposited on the apples, 47 of which had hatched. These decayed apples contained 39 burrows, and finally two moths were found in each of two jars. A repetition of this experiment resulted in obtaining no moths from three dipped apples and only two from three control apples.

TABLE I.—*Effects of nicotine sulphate on codling-moth eggs (1 and 2 days old) laid on fruit-tree foliage in laboratory.*

Experiment No.	Strength of nicotine-sulphate solution used, and control.	Number of eggs sprayed.	Eggs hatched.	Embryos aborted.	Eggs totally undeveloped.
			Per cent.	*Per cent.*	*Per cent.*
1	1:400	15	53.3	46.7	.....
	1:800	33	66.7	33.3	.....
	1:800+soap	15	63.7	.....	36.3
	Control	29	96.6	.....	3.4
2	1:1,000+soap	38	92.1	7.9	.....
	Control	75	98.7	.....	1.3
3	1:800	52	63.5	13.4	23.1
	Control	64	95.3	3.1	1.6
4	1:400	116	47.4	52.6	.....
	1:400+soap	158	49.2	47.4	3.4
	1:800+soap	213	79.8	20.2	.....
	Control	56	94.4	.....	5.6

To test the value of nicotine sulphate as an ovicide for codling-moth eggs, two experiments were started by E. H. Siegler, entomological assistant, June 5, 1918, at the bureau's field laboratory in Wallingford, Conn. In each experiment the eggs were deposited on apple-tree foliage by moths confined in oviposition jars. All of the treated eggs were thoroughly immersed in a solution of nicotine sulphate 1:800 plus common laundry soap (3 pounds to 50 gallons of water). After treatment each leaf was placed in a separate jar, with an apple as food for the larvæ as they hatched.

Experiment No. 1.—In this experiment the eggs were deposited June 3, and at the time of dipping them into the spray solution many had advanced to the red-ring stage. Seven leaves bearing 310 eggs were treated, while one leaf bearing 190 eggs was left untreated as a check. The results obtained show that out of 310 eggs treated, 296, or 95.48 per cent, hatched; out of 190 untreated eggs 96.84 per cent hatched. Many of the larvæ entered the apples and commenced feeding vigorously therein.

Experiment No. 2.—The eggs employed in this test were deposited June 4, and at the time of dipping them into the nicotine-soap solution none had advanced to the red-ring stage. Out of a total of 37 eggs, 35, or 94.59 per cent, hatched; out of 11 untreated eggs, 11, or

100 per cent, hatched. As in experiment No. 1, many of the newly hatched larvæ entered the apples and started their development therein.

EFFECTS OF NICOTINE SULPHATE ON NEWLY HATCHED LARVÆ OF THE CODLING MOTH IN THE LABORATORY.

From the preceding results it is evident that nicotine sulphate is not an efficient ovicide against the codling moth; and since the eggs probably hatched after the cessation of an injurious exhalation from the sprayed glass plate and leaves, the newly hatched larvæ perhaps died of starvation, rather than from the spraying. To test the effects of the exhalation from leaves sprayed one or more days previously upon the newly hatched larvæ, the following experiments were performed:

At 11.30 a. m. a pear-tree leaf was dipped into a solution of nicotine sulphate 1: 400, and another one into a solution 1: 800. At 1.30 p. m., when the leaves were dry, 15 newly hatched codling-moth larvæ were placed upon each leaf. At 4.30 p. m. 13 larvæ were dead on the first leaf, but only 6 dead on the second leaf. The leaves still emitted a nicotine-like odor. The following morning all the larvæ were dead and the leaves were wilted. At no time did any of them try to burrow into the leaves as do larvæ on leaves not treated with these solutions, and they crawled away from these leaves more than do larvæ on untreated leaves.

On May 4 a twig bearing foliage on an apple tree was dipped into a solution of nicotine sulphate 1: 400, and another twig into a solution of 1: 800. On May 14 a leaf was removed from each twig and then 28 newly hatched codling-moth larvæ were placed upon each leaf between two watch glasses. During the first day the larvæ burrowed considerably in the leaves and apparently were not affected. During the second day three of them died, but the leaves began to wilt. During the third day all of them died, and by this time the leaves had become dry. Between May 4 and 14 there had been much rain and on the latter date the leaves did not emit a nicotine-like odor. This experiment shows that the exhalation from the treated leaves did not affect the larvæ and that in all probability all of them finally died of starvation.

On May 18 the two twigs mentioned in the foregoing paragraph were again dipped into solutions of the same strengths, but this time soap was added at the rate of 2 pounds per 100 gallons of water. On May 19 six newly hatched larvæ were placed on each of two detached leaves as usual. The leaves still emitted a faint odor resembling that from the solutions. No larvæ died that day and only 4 of the 12 were found dead the following day. The leaves were slightly eaten.

On May 20, at 1 p. m., or the second day after the leaves had been treated, 13 codling-moth larvæ were placed on each of two detached leaves; at 3 o'clock 6 silkworms (2 days old) were also placed on each leaf; at 4.30 o'clock 10 of the 12 silkworms were dead, but not one of the codling-moth larvæ had succumbed. The following morning all of the silkworms were dead, but only 12 of the 26 codling-moth larvæ had succumbed. The leaves were slightly eaten.

On the third day after the leaves had been treated the preceding experiments were repeated. On this date only a few of the silkworms and none of the codling-moth larvæ died. The following morning all of the silkworms were dead, but the codling-moth larvæ did not die till later, when the leaves began to dry.

On the tenth day after the leaves had been treated the codling-moth larvæ tested apparently were not affected.

On various dates many small pears (22 mm. in diameter) with the calyx cups yet open were picked and then sprayed with solutions of nicotine sulphate. Some of these solutions contained soap in the proportion of 2 pounds to 100 gallons of water. The stem of each pear used was inserted into a small bottle containing water. From one to seven days after the pears had been sprayed six active codling-moth larvæ were removed from the oviposition jars and then placed on each pear; unsprayed pears were used as controls.

A glance at Table II shows that about 75 per cent of the larvæ tested were killed when placed upon pears which had been sprayed one or two days previously. It is also seen that the mortality decreases to about 25 per cent on the sixth and seventh days.

TABLE II.—*Effects on newly hatched codling-moth larvæ when placed upon small pears previously sprayed with solutions of nicotine sulphate in laboratory.*

Number of days after spraying pears when larvæ were tested.	Solution 1:400		Solution 1:800.		Solution 1:400+soap.		Solution 1:800+soap.		Control.	
	Number of larvæ tested.	Larvæ found dead on pears.	Number of larvæ tested.	Larvæ found dead on pears.	Number of larvæ tested.	Larvæ found dead on pears.	Number of larvæ tested.	Larvæ found dead on pears.	Number of larvæ tested.	Larvæ found dead on pears.
		Per cent.		*Per cent.*		*Per cent.*		*Per cent.*		*Per cent.*
1	18	72.2	18	77.7					18	0.0
2	18	77.7	18	72.2	18	61.1	12	25.0	6	16.6
3					6	100.0	6	66.6		
4	6	50.0	6	50.0	6	50.0	6	33.3		
5	6	83.3	6	66.6	6	33.3			6	16.6
6	12	25.0	6	33.3						
7	6	33.3	6	33.3						

EFFECTS OF NICOTINE SULPHATE ON EGGS OF TWO OTHER INSECTS.

Experiments similar to those performed on the eggs of silkworm moths and codling moths were also conducted upon the eggs of

potato beetles (*Leptinotarsa decemlineata* L.) and tussock moths (*Hemerocampa leucostigma* S. & A.).

Fifteen potato-plant leaves, each bearing a cluster of potato-beetle eggs (1 and 2 days old), were collected in a potato patch, and after the petiole of each leaf had been inserted into a bottle of water in the laboratory, 11 of the leaves were sprayed with solutions of nicotine sulphate 1:400 and 1:800 and the other four leaves were used as controls. The eggs thereafter were observed daily; practically all of them hatched, and the newly hatched larvæ were apparently not affected by remaining on the wilted leaves 1 or 2 days, after which they thrived when fed fresh and unsprayed leaves. Relative to the time of hatching there seemed to be little, if any, difference between the sprayed and unsprayed eggs. Similar results were obtained by spraying eight clusters of potato-beetle eggs in a potato patch with a solution 1:400 containing soap (2 pounds to 100 gallons water).

In order to obtain tussock-moth eggs of known ages, many large caterpillars of this moth were collected and were put in wire-screen cages, in which the remainder of the life history was completed. On various dates eggs from these cages and some from trees in the field were collected, placed in open pasteboard boxes, and then sprayed with four solutions of nicotine sulphate. Two of the solutions contained soap in the proportion of 2 pounds per 100 gallons of water. Some of the control eggs were not sprayed, while the others were sprayed with tap water; no difference in hatching between these was observed. The details of these experiments are summarized in Table III:

TABLE III.—*Effects of nicotine sulphate on eggs of tussock moth in laboratory.*

Strength of nicotine-sulphate solution used, and control.	Eggs collected in cages.						Eggs collected in field. Age probably from freshly-laid eggs to those ready to hatch.		
	Eggs 1 and 2 days old.			Eggs 2 and 3 days old.					
	Number of egg masses tested.	Egg masses that hatched.	Egg masses that did not hatch.	Number of egg masses tested.	Egg masses that hatched.	Egg masses that did not hatch.	Number of egg masses tested.	Egg masses that hatched.	Egg masses that did not hatch.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*
1:400	.....	.....	.....	4	25.0	75.0	12	83.3	16.7
1:800	.....	.....	.....	4	62.5	37.5	.....	.....	.....
1:800+soap	4	25.0	75.0	4	25.0	75.0	33	87.9	12.1
1:1000+soap	4	37.5	62.5	.....	.....	.....	45	82.2	17.8
Control	3	83.4	16.6	4	87.5	12.5	45	93.3	6.7

It is seen from Table III that nicotine sulphate is not efficient against the eggs of the tussock moth; the percentages given for the masses of eggs that did not hatch, however, are too low, because the final examination showed that as a rule when a control and a sprayed

mass of eggs (both recorded as hatched) were closely observed, more larvæ had emerged from the former than from the latter. The ones sprayed with nicotine sulphate were slightly retarded in hatching, and the eggs in most of the masses which did not hatch contained aborted embryos, while the remainder of them were totally undeveloped.

DISCUSSION AS TO HOW NICOTINE SULPHATE ACTS AS AN OVICIDE AND LARVICIDE.

It is difficult to determine accurately how any insecticide kills a larva or an adult insect, and in the light of our present knowledge along this line it would perhaps be impossible to ascertain definitely how an ovicide affects insect eggs. For this reason no attempt was made in the present investigation to determine how nicotine sulphate killed the eggs tested. Nevertheless a little theory on this subject may not be out of place here.

Before attempting to explain how nicotine sulphate acts as an ovicide, it is first necessary to know something about the coverings of an insect egg. It is well known, as compiled by Packard (*8, p. 520*), that a ripe insect egg has two coverings. The external one, the eggshell or chorion, is usually thick and hard; it is pierced by one or more minute canals, the micropyles, and consists of two chitinous-like laminæ kept in close apposition by means of numerous minute pillars. The internal covering, the vitelline membrane, is always thin and delicate. The developing embryo inside the egg is supposed to breathe directly through these coverings as does a chick embryo through the shell of a hen's egg.

According to the results already presented, it was ascertained that freshly laid eggs, sprayed with solutions of nicotine sulphate, were affected more than were older eggs likewise treated. The chorions of these eggs were not as hard as those of the older eggs. This fact alone may explain the difference in the mortality recorded. Since it is scarcely possible that the spray solutions passed through the eggshells, there remain two possible methods of explaining the death of the eggs sprayed: (1) Upon evaporation of the spray solutions there was usually left a thin film on the leaves sprayed, and perhaps also on the eggs. This film on the eggs might have decreased the aeration through the eggshells and thus caused death by suffocation. (2) Since practically all of the aborted embryos appeared to have died during the last stage of development, the preceding view does not seem to have much weight. As the sprayed surfaces continued to emit a nicotine-like odor for some time after the spray solutions had been applied, it seems reasonable to suppose that the embryos were killed by breathing the exhalation from the sprayed surfaces through the eggshells. Nicotine is a nerve poison, and the more highly developed

the nervous system the more effective the poison. This fact probably explains why practically all of the embryos that died succumbed during the last stage of development.

Feytaud (*3*) described five stages in the embryology of (*Eudemis*) *Polychrosis botrana* Schiff. and of (*Phalonia*) *Conchylis ambiguella* Hbn., and he treated many eggs of these moths with various strengths of pure nicotine and soap. The resulting mortality varied considerably, but even the strongest solution (1 : 666) used did not prove efficient. He tested the eggs in the various stages of development, but in almost every case in which the embryos died they succumbed during the last stage.

Lovett (*4*) sprayed apple-tree foliage with solutions of nicotine sulphate, and after several hours, when the leaves were perfectly dry, he placed many small tent caterpillars (*Malacosoma pluvialis* Stretch) on these leaves. He states that these caterpillars showed a decided aversion for the sprayed leaves; all of them soon became sick and a large percentage of them died. On the third day after the foliage had been sprayed more caterpillars were placed on the same leaves and similar results were obtained. The leaves were not eaten. Lovett performed other experiments in which the caterpillars slightly ate the leaves which had been sprayed several hours previously. In this case the action of the nicotine was quick and decisive. These results agree with those given in the preceding pages.

Theoretically nicotine sulphate is nonvolatile, although we know from experience that the commercial 40 per cent nicotine sulphate (the kind used in all the preceding experiments) is more or less volatile. Moore and Graham (*7*) state that pure nicotine sulphate is nonvolatile, and demonstrated that its vapor or exhalation (if either one is given off) did not kill the insects tested. They also state that commercial 40 per cent nicotine sulphate contains from 1 to 2 per cent of free nicotine, whose vapor did kill the insects tested. Moore and Graham claim that when spray solutions are prepared by using commercial nicotine sulphate, hard water, and soap, the nicotine sulphate is decomposed, setting free the nicotine; the amount of decomposition depends upon the amount of alkalies contained in the solutions. This view easily explains the presence of a thin film (already mentioned several times) left upon evaporation of the spray solution, which is certainly the nonvolatile portion of the nicotine sulphate contained in the solution. For some time after the application of the solution the film continues to emit an odor and its exhalation is more or less toxic to young larvæ, showing that it is not pure nicotine sulphate according to Moore and Graham.

Moore and Graham (*7*) state that 12 days after lettuce in a greenhouse had been sprayed with a solution of commercial 40 per cent nicotine sulphate, it still bore nicotine.

To determine how long nicotine sulphate may remain on fruit-tree foliage after the application of the spray solution, the following experiments were performed by McIndoo. On September 10 a small pear tree was sprayed with a solution of commercial 40 per cent nicotine sulphate 1:800, containing fish-oil soap (2 pounds to 100 gallons water). On various days thereafter about a quart of the sprayed leaves were collected on each recorded date; the leaves, after being ground in a meat grinder, were then mixed thoroughly with water containing sodium carbonate. Upon distilling this mixture a distillate containing nicotine was obtained on each day tested up to the thirty-fifth day after the leaves had been sprayed. On the forty-second day after applying the spray solution only an indication of a precipitate was observed, but concluding from the precipitates obtained prior to this date the amounts of nicotine present in the distillates seemed to decrease irregularly from the first to the forty-second day: soon after which the remaining leaves fell from the trees. During these tests there was comparatively little rainfall; nevertheless the results of the tests indicate that considerable rainfall is required to remove all of the nicotine sulphate adhering to the sprayed leaves. The details of these tests are presented in Table IV:

TABLE IV.—*Tests on various dates using pear-tree leaves which had been sprayed on Sept. 10 with a solution of commercial 40 per cent nicotine sulphate (1:800) containing soap to show the presence of nicotine.*

Date.	Number of days after leaves had been sprayed.	Kind of precipitate obtained using—		Amount of rainfall.	Remarks.
		Phosphomolybdic acid.	Silicotungstic acid.		
				Inches.	
Sept. 11	1	Heavy	Heavy	0.00	Sprayed leaves emit nicotinelike odor.
Sept. 12	2	do	do	.00	Do.
Sept. 12	(1)	None	None	.00	Unsprayed leaves on another tree were used.
Sept. 13	3	Heavy	Heavy	.00	Sprayed leaves do not emit nicotinelike odor.
Sept. 14	4	do	do	.14	
Sept. 15	5			.01	
Sept. 16	6			.08	
Sept. 18	8	Fair	Faint	.00	
Sept. 24	14	do	Very faint.	T.	
Sept. 27	17			.07	
Sept. 28	18			.16	
Oct. 1	21	Fair	Very faint.	.00	
Oct. 4	24			.01	
Oct. 5	25			.20	
Oct. 8	28	Fair	None	.07	
Oct. 9	29			.35	
Oct. 11	31			.01	
Oct. 12	32			.36	
Oct. 15	35	Very faint.	None	T.	
Oct. 19	39			.89	
Oct. 20	40			.01	
Oct. 22	42	Indication.	None		
Total amount of rainfall during tests				2.36	

[1] Control.

At the suggestion of Mr. V. I. Safro, McIndoo washed separately 50 sprayed pear-tree leaves in 50 cc. of water. The resulting filtrate was acidified with hydrochloric acid and then tested for the presence of nicotine by adding phosphomolybdic acid and silicotungstic acid. Each test apparently showed the presence of nicotine. Fifty unsprayed leaves were likewise tested as a control; no precipitate was observed. One hundred unsprayed leaves were also tested, using the same amount of water; this time a precipitate was observed, and the same result was obtained thereafter on several occasions. Only green and unbroken leaves were used in these tests. At all times there is more or less foreign organic matter in the form of dust on the leaves; this is readily seen in microscopical sections through unsprayed leaves, and alkaloidal reagents precipitate it, as well as the nicotine which may be present. Consequently the preceding method should not be regarded as reliable; nevertheless, Mr. Safro (*9*) has published his method and says:

> Generally we are able to obtain a definite indication of the presence of nicotine in as little as 25 cc. of water by using five leaves that had been sprayed at the usual strength (about 0.05 of 1 per cent nicotine).

On the fourth day after the pear tree used in the experiments had been sprayed, about a quart of the sprayed leaves were collected and washed in water containing sodium carbonate, each leaf being washed separately. Next the leaves were washed in running water for 5 minutes, and were finally ground and tested as described above. By adding phosphomolybdic acid to the resulting distillate, a faint precipitate was obtained, but none by adding silicotungstic acid. On the eighth day after the leaves had been sprayed, the test was repeated, but this time the leaves were washed for 10 minutes in running water. No precipitate was observed in this test even by adding phosphomolybdic acid. In each of the two foregoing tests the water containing the sodium carbonate and foreign matter removed from the leaves was distilled. Adding either acid to the resulting distillate invariably produced a precipitate, but in none of the tests with sprayed leaves did the distillate ever emit a nicotine odor. The second experiment described above indicates either that the spray solution did not pass into the leaves or that the amount of nicotine still held by them was too small to be detected by the method employed. The following results will substantiate the former view:

A small quantity of nicotine-sulphate solution (1:800) containing fish-oil soap (2 pounds to 100 gallons of water) was colored with carmine acid (Grübler's Carminsaur) and an equal quantity with indigo carmine (sodium sulphindigotate). Several leaves on a pear tree were sprayed with each of the colored solutions, and two entire detached leaves were submerged in each solution for 15 minutes; the

petioles of the leaves were left projecting above the surfaces of the solution. An hour later the four treated leaves were put into absolute alcohol and a day later a few of the stained leaves on the tree were likewise treated. The absolute alcohol did not dissolve or scatter either one of the stains, and the only other reagents used were xylol and Canada balsam; these also did not scatter the stains. A study of the sections made shows much stain on the outside of the sprayed and submerged leaves. While none was observed inside the sprayed leaves, it was usually present inside the submerged ones and the most of it seems to have passed through the ventral surfaces of the leaves. Its passage may have been aided by the stomata which occur exclusively on the ventral surface of these leaves; botanists, however, say that the stomata are so small (0.0006 mm. and less) that neither dust nor water can pass through them into the plant. According to the above results the spray solutions did not pass into the leaves sprayed, nor did the dust in the film of adhering nicotine sulphate enter the stomata.

SUMMARY OF EXPERIMENTS CONDUCTED IN LABORATORY.

Nicotine sulphate as an ovicide, with one exception, was found inefficient against all of the eggs tested—namely, those of the silkworm moth, codling moth, tussock moth, and potato beetle. The eggs sprayed with it were variously affected, depending on the strength of the spray solution used, on the age of the eggs tested, and whether or not the solution contained soap. Upon the eggs of three of the species of insects used there was practically no difference in effects between solutions containing soap and those without soap, although those with soap were much more effective upon the eggs of the tussock moth. Comparing the effects of the spray solution 1:800, the strongest one of the economic solutions used, the percentages of eggs sprayed with it that failed to hatch are as follows: Ninety-nine per cent of the freshly laid eggs of the silkworm moth, but only about 75 per cent of the older eggs of the same insect; about 20 per cent of the codling-moth eggs on apple-tree foliage; 75 per cent of the tussock-moth eggs (1 to 3 days old); and about 12 per cent of those of the same insect which had been collected in the field; and practically none of the potato-beetle eggs.

The effects of the exhalation from leaves sprayed with solutions of nicotine sulphate varied considerably, depending on the larvæ tested and the strength of the solutions used. Again comparing the effects of the solution 1:800, all of the newly hatched silkworms and codling-moth larvæ placed upon leaves sprayed two hours previously died, but the silkworms succumbed the more quickly; all of the silkworms but only a small percentage of the codling-moth larvæ placed upon leaves sprayed 24 hours previously died.

Seventy-seven per cent of the newly hatched codling-moth larvæ placed upon pears sprayed 24 hours previously with a solution of nicotine sulphate 1:800 died, but only 33 per cent of those placed upon pears sprayed a week previously died.

Relative to the control of the codling moth, the following briefly summarizes the more important points herein recorded: About 20 per cent of the freshly laid eggs sprayed with a solution of nicotine sulphate 1:800 failed to hatch, and one-third of the remaining embryos that emerged died before they entered pears sprayed a week previously. Hence about one-half of the eggs and larvæ had been destroyed up to the time when the remaining larvæ entered the sprayed pears; a large percentage of the latter larvæ died, as about 60 per cent of the pears did not become wormy. According to these laboratory results nicotine sulphate does not seem to be efficient against the codling moth, although only one application of it was made; nevertheless its effectiveness would certainly be increased in proportion to the number of its applications and to the amount of rainfall.

EXPERIMENTS CONDUCTED IN ORCHARDS.

According to the preceding laboratory results nicotine sulphate would not seem to be efficient against the codling moth. To determine this from the practical viewpoint the following experiments were conducted:

EXPERIMENTS PERFORMED AT BENTON HARBOR, MICH.

The experimental work conducted at Benton Harbor consisted in testing the relative efficiency of nicotine sulphate when combined with soap and when combined with soap and arsenate of lead in contrast with the efficiency of arsenate of lead when combined with lime-sulphur at summer strength. The experiments were made in a sod orchard about 50 years old, and each of the four plats selected consisted of 16 trees.

All of the applications throughout the season were made with the same power sprayer and at a pressure well above 100 pounds. The spray was delivered through the Vermorel type of nozzle. Although the experiments were started with the calyx application, all of the plats, including the check (No. 4), were given the cluster bud application.

The set of fruit was scattered and rather light, being lightest in plat No. 3, but it was sufficient to give reliable experimental results. In order that trees with as uniform a crop as possible might be secured throughout the different plats, five count trees in each plat were not selected until after the fruit had set. The fallen fruit was

collected once a week and examined for codling-moth injury, and at picking time the picked fruit was also examined. The results of these examinations are given in Table V.

TABLE V.—*Codling moth injury as shown by examination of both fallen and picked fruit from experimental plats at Benton Harbor, Mich., 1917.*

No. of plat.	Number of applications and brief formula of each.	Fruit record.					
		Number of larval entrances at—			Number of wormy apples.	Total number of apples examined.	Percentage of total number of apples free from worms.
		Calyx.	Side.	Stem.			
1	1 application of lime-sulphur and 3 applications of lime-sulphur + 1 pound arsenate of lead to 50 gallons water	191	277	14	336	6,543	94.71
2	1 application of lime-sulphur and 3 applications of nicotine sulphate 1:800+soap	559	662	71	1,249	9,924	87.41
3	1 application of lime-sulphur and 3 applications of nicotine sulphate 1:800+soap+0.5 pound of arsenate of lead to 50 gallons of water	40	195	4	231	2,949	92.15
4	1 application of lime-sulphur (check)	2,032	607	93	2,484	6,060	59.00

Reference to Table V shows that nicotine sulphate (plat No. 2) gave a control of only 87.41 per cent, while arsenate of lead (plat No. 1) gave a control of 94.71 per cent. There is thus seen to be no practical advantage in combining arsenate of lead with nicotine sulphate in sprays designed to control the codling moth (plats Nos. 1 and 3).

EXPERIMENTS PERFORMED AT GRAND JUNCTION, COLO.

Experiments similar to the preceding were also performed at Grand Junction, Colo. Of the 12 plats sprayed, only 2 were sprayed with nicotine sulphate, but since the results obtained using arsenate of lead vary so greatly, the data from 4 of the latter plats are given in Table VI, so that the results from the plat sprayed with nicotine sulphate may be compared with those from the plats sprayed with arsenate of lead alone and also with the results from the plat sprayed with arsenate of lead and nicotine sulphate combined. In plats on which it was applied (i. e., all except plats Nos. 10, 14, and 15), the calyx application was made with a Bordeaux type of nozzle which delivered a fairly coarse and driving spray; a mist type of nozzle was used for all subsequent applications. With this exception the same spraying equipment was used for all plats except the checks.

At various times throughout the growing season and at harvest time the apples on eight trees in each plat (four in each of the two check plats) were examined; the results of these examinations, together with the treatment of the several plats, are given in Table VI.

TABLE VI.—*Codling-moth injury as shown by examination of both fallen and picked fruit from experimental plats at Grand Junction, Colo., 1917.*

Plat No.	Formula of insecticide.	Number of applications.			Total number of apples examined.	Fallen apples free from worms.	Harvested apples free from worms	Total apples free from worms.
		For first brood.	For second brood.	Total.				
						Per cent.	*Per cent.*	*Per cent.*
2	1 pound of powdered arsenate of lead to 50 gallons of water	4	2	6	23,508	37.75	72.16	62.09
3	Nicotine sulphate (1:800)	4	2	6	29,881	17.32	58.33	37.96
4	1 pound of powdered arsenate of lead to 50 gallons of water plus nicotine sulphate (1:800)	4	2	6	24,003	40.97	84.17	67.50
8	1 pound of powdered arsenate of lead to 50 gallons of water	3	2	5	38,874	48.28	82.31	73.49
9	Same as above	4	3	7	47,773	47.74	85.53	76.53
10	Same as above	[1] 3	2	5	37,628	22.83	60.69	46.33
14 and 15	Check (unsprayed)	.....	.....	.....	33,882	7.36	15.01	8.72

[1] All three were cover applications, the calyx application being omitted.

Although the results in the preceding table vary considerably, it is seen nevertheless that nicotine sulphate when used alone was inefficient (plat No. 3).

EXPERIMENTS PERFORMED AT ROSWELL, N. MEX.

The experimental work conducted at Roswell consisted in a comparison of the efficiency of nicotine sulphate with that of arsenate of lead alone and also with that of arsenate of lead combined with nicotine sulphate. For this purpose four plats, lying in a 640-acre tract of apple trees, were selected; they were similar in all respects and the trees, about 20 years old, were of the Ben Davis variety. Following the regular 5-spray schedule, all the plats, except the check (No. 4), were sprayed on the following dates: April 25, May 15, June 14, July 18, and August 14. During the first application about 21 gallons of spray material were applied to each tree, but during each subsequent application only about 17 gallons per tree were used. Bordeaux nozzles were used for the calyx application and a mist type for the other applications. A power sprayer, holding 200 gallons, was employed, and the pressure was maintained at 200 pounds with three leads of hose.

During these experiments the dates and amounts of rainfall are as follows: May 6, 0.23 inch; July 19, 0.03 inch; July 20, 0.03 inch; August 1, 0.54 inch; August 2, 0.47 inch; August 15, 0.15 inch; August 17, 0.60 inch; and August 18, 0.93 inch, giving a total of 2.98 inches.

The details pertaining to the plats, formulas of application, and results of the foregoing experiments are given in Table VII.

TABLE VII.—*Codling-moth injury as shown by examination of both fallen and picked fruit from experimental plats at Roswell, N. Mex., 1917.*

Plat No.	Number of applications and formula of each.	Fruit record.			
		Total number of apples examined.	Fallen apples free from worms.	Harvested apples free from worms.	Total apples free from worms.
			Per cent.	*Per cent.*	*Per cent.*
1	5 applications of 1 pound of powdered arsenate of lead to 50 gallons of water	[1] 33,472	93.64	97.66	96.88
2	5 applications of 1 pound of powdered arsenate of lead to 50 gallons of water+nicotine sulphate (1:800)+¾ pound of laundry soap	[2] 7,011	85.55	98.99	97.00
3	5 applications of nicotine sulphate (1:800)+¾ pound of laundry soap to 50 gallons of water	[3] 6,170	88.01	93.43	91.94
4	Unsprayed	[4] 14,401	52.06	50.01	51.53

[1] On 6 trees. [2] On 4 trees. [3] On 4 trees. [4] On 12 trees.

From Table VII it is seen that the trees sprayed with nicotine sulphate (plat No. 3) yielded a crop of apples 92 per cent sound, while those sprayed with arsenate of lead (plats Nos. 1 and 2) yielded a crop 97 per cent sound, and that the addition of nicotine sulphate to the arsenate of lead mixture (plat No. 2) did not materially increase the percentage of sound fruit.

CONCLUSIONS FROM FIELD EXPERIMENTS.

According to the work conducted during the season of 1917, it is shown that nicotine sulphate 1:800 with soap gave a fair degree of control for the codling moth at Benton Harbor, Mich., and at Roswell, N. Mex., but that it was not as effective as 1 pound of powdered arsenate of lead to 50 gallons of water; and also that there was no practical advantage in combining arsenate of lead and nicotine sulphate in sprays designed to control the codling moth. Of course it is well known that nicotine sulphate controls aphids on fruit trees, but this phase of the subject is not considered in this paper. At Grand Junction, Colo., where the infestation was much heavier, nicotine sulphate 1:800 without soap was inefficient against the codling moth.

LITERATURE CITED.

(1) [De Sellem, F. E.]
1916. Nicotine sulfate for codlin moth control. *In* Ann. Rept. Hort. Dept., Yakima Co., Wash., p. 62–72.

(2) Eaton, J. S., and Waterbury, H. E.
1917. Codlin moth experimental work in Ross orchard. *In* Ann. Rept. District Hort. Inspector, Yakima Co., Wash., p. 27–42.

(3) Feytaud, J.
1912. Action des insecticides sur les œufs de la cochylis et de l'eudémis. *In* Bul. Soc. d'Etude et de Vulgarisation de la Zool. Agr., Bordeaux, p. 1–20.

(4) Lovett, A. L.
1917. Nicotine sulphate as a poison for insects. *In* Jour. Econ. Ent., v. 10, no. 3, p. 333–337.

(5) ———
1918. Nicotine sulphate an effective ovicide for codling moth eggs. Notes *in* Jour. Econ. Ent., v. 11, no. 1, Feb., p. 149–150.

(6) McIndoo, N. E.
1916. Effects of nicotine as an insecticide. *In* Jour. Agr. Research, v. 7, no. 3, p. 89–122, 3 pl.

(7) Moore, William, and Graham, S. A.
1917. A neglected factor in the use of nicotine sulphate as a spray. *In* Jour. Agr. Research, v. 10, no. 1, p. 47–50.

(8) Packard, A. S.
1903. A text-book of entomology. New York.

(9) Safro, V. I.
1917. How to test for the presence of nicotine on sprayed plants. *In* Jour. Econ. Ent., v. 10, no. 5, Oct., p. 459–461.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 939

Contribution from the Bureau of Animal Industry

JOHN R. MOHLER, Chief

Washington, D. C. ▲ April 23, 1921

THE TURKEY AN IMPORTANT FACTOR IN THE SPREAD OF GAPEWORMS.[1]

By B. H. Ransom, *Chief, Zoological Division.*

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EXAMINATION OF MARKET CHICKENS AND TURKEYS.

FOR THE PURPOSE of collecting some statistics on the prevalence of gapeworms (*Syngamus trachealis*) in the vicinity of Washington, D. C., and of obtaining material for use in experiments, examinations were made of the tracheas of 635 chickens killed for sale at poultry stalls in Center Market during the latter half of December, 1916, and the months of January and February, 1917. Nothing definite is known as to the ages of these chickens except that the chickens were all obviously large enough for food purposes. Probably none were less than six months old, most of them likely were older, and no doubt many were a year old or more. No gapeworms were found.

At the same time the tracheas of turkeys from the same market were similarly examined. The ages of the turkeys, as in the case of the chickens, were uncertain, but undoubtedly all the turkeys were at least 6 months old, and many of them were probably more than a year old. During the period mentioned the tracheas from 386 turkeys were examined. The next year, beginning March 2, 1918, an-

[1] The writer is greatly indebted to Dr. Lawrence Avery, of the Bureau of Animal Industry, for assistance rendered in carrying out the investigations reported in this paper.

other series of 115 was examined, and during the month of November, 1918, a final series of 178; in all, 679 turkey tracheas were examined. In the case of the chickens practically the entire trachea was obtained from each bird, but in the case of the turkeys usually only a portion of the trachea was secured, so that as a rule an examination of the entire trachea could not be made.

In the first series of turkey tracheas (386 examined in December, 1916, and January and February, 1917) gapeworms were found in 89, and characteristic lesions marking the former location of gapeworms in 3 others, a total of 92, or 23.8 per cent. In the second series (115 examined in March, 1918) worms were found in 17 and a gapeworm lesion in 1 other, a total of 18, or 15.7 per cent. In the third series (178 examined in November, 1918) worms were found in 43, or 24.2 per cent. The percentage of turkey tracheas infested out of the total number examined was 22.5 per cent. It is possible that the lower percentage observed among the tracheas examined in March as compared with those examined in December, January, and February, and in November following, was the result of having more incomplete specimens of tracheas than were generally secured in the two latter series. In any event, in view of the fact that throughout the three series incomplete tracheas were the rule, it appears quite certain that more cases of infestation would have been found if the entire trachea could always have been secured. It is, therefore, fair to conclude that the percentage of infestation among the turkeys examined was in reality higher than the 22.5 per cent actually found. Counting the gapeworm lesions found without worms attached as representing worms, and counting the paired male and female as a single worm, a single worm was present in 91 cases, 2 worms in 36 cases, 3 worms in 14 cases, 4 worms in 6 cases, 5 worms in 3 cases, 7, 9, and 18 worms in 1 case each.

In view of the complete absence of gapeworms from a large series of adult and approximately adult chickens, and their common occurrence in a similar series of adult and approximately adult turkeys, all obtained at the same market and at the same season of the year, it would appear that adult chickens are poorly adapted as hosts for gapeworms. Evidently the occurrence of gapeworms in adult chickens in the general locality of Washington, D. C., must be exceedingly rare, though, as is well known, gapeworms are of frequent occurrence in young chicks in this as well as in many other localities. On the other hand, it is evident that not merely young turkeys may harbor gapeworms, but that in the locality mentioned these parasites are very common in adult turkeys. Although, as noted, the ages of the various turkeys from the Washington market were uncertain, many of the turkeys examined were no doubt considerably more than

a year old. That turkeys above 3 years of age may harbor gapeworms is established by the fact that a turkey which was kept at the Bureau of Animal Industry Experiment Station, Bethesda, Md., for three years after it was brought there was found after its death to be infested with a pair of gapeworms.

EXPERIMENTAL WORK.

Experiments in artificially infecting chickens of various ages with gapeworms were carried out as follows: To provide material for infecting the chickens, cultures were made at first from gapeworms collected from the tracheas of turkeys. Later many of the worms collected from the artificially infected chickens were also used in making cultures. The worms were chopped into small pieces and the eggs released by tearing apart the fragments of the uteri in a small quantity of water. The water containing particles of worms and the eggs was spread on the surface of a sterilized medium culture made from chicken feces mixed with powdered animal charcoal. This was kept moist in a petri dish and allowed to incubate at room temperature. After about two weeks' incubation a large proportion of the eggs contained fully developed larvæ, many of which commonly hatched and continued active for long periods after hatching. The cultures were then ready for use and were fed to the chickens by placing small portions scraped from the surface of the culture medium directly into the mouth and making sure that the birds swallowed the material. The chickens used in the experiments, except the adults, were hatched in incubators and kept from exposure to gapeworm infection until used. Usually only one feeding was given, and in most cases the chicken, if it did not die earlier, was killed two weeks after feeding the infectious material. Occasionally chickens were killed for examination in less than two weeks after infection. The tracheas and lungs were examined for gapeworms, the latter by dissection in physiological salt solution, a lens being used for the discovery of small, incompletely developed worms. Altogether 139 chickens of different ages were thus fed infectious gapeworm material. The results are shown below.

Results of artificially infecting chickens with gapeworm material.

Age of chickens when fed.	Number fed.	Number infected.	Per cent infected.
1 to 4 weeks	47	41	87
5 to 8 weeks	32	27	84
9 to 20 weeks	32	21	66
21 weeks to adult	28	8	29

From the data shown in the table it seems evident that as chickens grow older they tend to become less susceptible to infection with gapeworms. Apparently, therefore, the most likely reason no gapeworms were found among the 635 chickens from the Washington market was that these chickens when examined had reached an age at which they were no longer favorable hosts for gapeworms. Probably some of them had been infested earlier in life but had afterwards lost their parasites. How long gapeworms will persist in young chickens that do not succumb to the infestation is uncertain. That adult chickens, however, in those unusual cases in which they become infested with gapeworms, are likely to harbor the parasites only temporarily is indicated by some of the findings in the following experiments:

Twelve adult chickens a year old or more were fed gapeworm material from cultures on April 26, 28, 30, May 2, 4, 7, 9, and 11, altogether receiving 8 feedings, except one which was killed May 7, before feeding time, and hence received only 5 feedings. Material from the same cultures was fed to 12 1-week-old chicks April 24, 28, 30, May 2, and 4. All the young chickens died of gapes in 11 to 27 days after the first feeding, and all were found infested with gapeworms. Except the one killed May 7, 11 days after the first feeding, the adult chickens were killed 16 to 29 days after the first feeding and 1 to 14 days after the last feeding. Gapeworms were found in only 3 out of the 12. The lungs of one killed 16 days after the first feeding and 1 day after the last feeding contained an unpaired female 2.5 mm. long, and in the trachea were two pairs, the females being 6.5 mm. and 10 mm. long, respectively. The 10 mm. female was producing eggs. Another chicken that was killed 18 days after the first feeding and 3 days after the last feeding harbored in the trachea a single pair of worms. The female of this pair measured 13 mm. in length and was depositing eggs. In the trachea of the third chicken, killed 29 days after the first feeding and 14 days after the last feeding, there were 7 dead males without females, 4 living males without females, 3 living females with dead males, 1 living female with a living male, and 1 living female without a male. The last two females contained apparently viable eggs, but in the other three females the eggs were apparently nonfertile, dark, and unnatural in appearance. All the worms, alive and dead, were firmly attached to the trachea. The living worms were enveloped in a thick layer of mucus.

On another occasion 6 adult chickens probably a little less than a year old were fed with a gapeworm culture. Seven days later one was killed. No worms were found. A second chicken, killed 8 days after feeding, had one unpaired worm, one pair of coupled worms in the lungs, and 14 pairs of coupled worms in the trachea, all imma-

ture, those in the trachea evenly distributed from bronchi to larynx. The females in the trachea measured 3 to 6 mm. in length. The worms in the trachea were enveloped in masses of very viscid, tenacious mucus and none apparently were attached to the wall of the trachea. Another chicken was killed 11 days after feeding and was found to be free from parasites. Twenty-eight days after feeding, microscopic examination failed to show gapeworm eggs in the feces of the three surviving chickens. The following day one of them was killed and found to be free from parasites. Thirty-one days after the first feeding the two surviving chickens were fed with a gapeworm culture. Eight days after this feeding the chickens were killed. One of them was free from parasites, the other had one young worm in the lungs, and a pair of coupled worms in the trachea. The female of this pair was ruptured in removal but measured 15 mm. or more in length and contained eggs ready for oviposition. This pair of worms was enveloped in a mass of tenacious mucus. Evidently the worms in the trachea came from the first feeding of gapeworm material, 39 days before the chicken was killed.

The findings in the case of one of the chickens referred to suggest very strongly that the worms that had succeeded in establishing themselves in the trachea were having difficulty in maintaining themselves, as 10 of the 15 males present 29 days after infection were dead though firmly attached to the trachea, and as the living worms, both males and females, were enveloped in a thick layer of mucus, indicative perhaps of a strong reaction, on the part of the host, that would soon destroy them. In two of the other chickens also the unusually large masses of mucus enveloping the worms suggest the likelihood of the early death or expulsion of the parasites. In any event it is evident, since in the one instance a large proportion of the gapeworms present 29 days after infection had died after reaching maturity, that gapeworms in adult chickens, when they succeed in establishing themselves in the trachea, sometimes die within a month after infection, infestation with gapeworms in such cases thus being of brief duration. Further evidence of the transient nature of gapeworm infestation in adult chickens is given by Waite (1920, p. 115), who fed about 150 earthworms from gapeworm-infested chicken runs to three yearling hens. Fifteen days later gapeworms could be distinctly seen in the tracheas of two of them by looking down their throats in a good light. Two weeks later the worms had disappeared, and when the hens were killed and examined 72 days after the feeding with the earthworms, no signs of gapeworms were found.

In view of the difficulty of infecting adult chickens with gapeworms, the likelihood of the brief duration of infestation in cases in

which the worms succeed in developing to maturity in adult chickens and the failure to find any gapeworms among a large number of adult chickens obtained from a certain market, though the parasites were of common occurrence in adult turkeys from the same market, it seems evident that adult chickens are not likely to be of great importance as carriers of gapeworms. On the other hand it is certain that sometimes they may harbor gapeworms for brief periods at least.

Besides the fact that adult chickens occasionally may be infected experimentally may be cited the following instance of infestation following exposure to infested ground. A chicken at least 22 months old and probably considerably more than 2 years old died at the Bureau of Animal Industry Experiment Station with a history indicating that it had been kept at least a year in a pen that had previously been used in gapeworm experiments. This hen was in poor condition, greatly emaciated, and devoid of the usual subcutaneous and visceral fat. Besides nematodes and tapeworms in the intestine there were found in the trachea a female gapeworm 21 mm. long with a male 5 mm. long, and another female about 10 mm. long, with a male 4.6 mm. long. The smaller female contained eggs, but well-developed eggs were not found in the larger female.

This case perhaps should be taken as an indication of the possibility that as chickens become old and debilitated their susceptibility to gapeworms tends to increase again after having diminished as they approached maturity. Such an explanation would be in harmony with the frequently observed fact that certain parasites are more common in young and very old animals than in those of middle age. No definite conclusion, however, is possible from a single case.

In marked contrast to adult or nearly adult chickens, adult turkeys can easily be infected experimentally with gapeworms, as would be expected from the fact that the worms have been found to be naturally common among adult turkeys. The following experiment shows the results of attempts to infect chickens approaching maturity, young chickens, and adult turkeys, respectively, using infective material from the same source.

Three chickens 21 weeks old at the beginning of the experiment were fed portions of gapeworm cultures November 29, December 18, 20, 27, January 3, 31, February 28, and March 31. Beginning February 28 the chickens were kept on ground that was contaminated with gapeworms. The feces of these three chickens were examined January 3, 13, 17, 25, 31, February 8, 15, 22, 28, and March 28, and the feces of two of them also on April 22, always with negative results. One of the chickens was killed on April 8 and was free from gapeworms, as were also the other two, killed on May 24.

Some of the culture fed on January 31 was fed on February 7 to three chicks 8 weeks old, and these chicks when killed 14 days later

harbored, respectively, 92, 75, and 36 pairs of gapeworms in their tracheas, the females ranging in size from 4 to 11 mm. Besides the worms in the trachea there were a few immature gapeworms in the lungs of each chicken.

Some of the same culture was fed on February 7 to three turkeys nearly a year old. Nineteen days later one of the turkeys was observed to be sick and was killed. There were no gapeworms found in the lungs, but 483 pairs were present in the trachea, the females averaging 24 mm. in length. The feces of the two remaining turkeys were first examined 21 days after infection and at this time contained large numbers of gapeworm eggs. The birds were coughing and there was a brown crust on their bills, formed by the drying of expectorated mucus. On March 17, 38 days after infection, these two turkeys were still coughing, but the brown crust was no longer present on their bills. On April 14, 66 days after infection, gapeworm eggs were still present in the feces. April 29, one of the turkeys which had been ailing was killed, the lungs and one bronchus being found affected with a gangrenous necrosis. The trachea contained 22 pairs of gapeworms, the females averaging 33 mm. in length; also many broken pieces of dead worms were found. The third turkey was kept alive. December 16, 10 months after infection, an examination of the feces of this turkey failed to show gapeworm eggs.

In this experiment adult turkeys (nearly a year old) and young chickens (8 weeks old) became heavily infested as the result of a single feeding with gapeworm material, while chickens approaching maturity (21 weeks old) that were fed repeatedly with gapeworm material (including material from the same culture as that fed to the turkeys and the young chickens) failed to become infested. Evidently, therefore, adult turkeys and young chickens are much alike in their susceptibility to gapeworm infection, and in this respect both are quite different from adult chickens or chickens approaching maturity.

FACTORS IN THE SPREAD OF GAPEWORMS.

From the results of the investigations briefly recorded above, it would seem that turkeys are an important factor in the spread of the gapeworm, and that adult chickens are relatively unimportant as carriers of the parasite. In the perpetuation of gapeworms from year to year on infested poultry farms the two chief factors appear to be turkeys and contaminated soil. Whether guinea fowls are like turkeys in commonly harboring gapeworms throughout life or whether they are like chickens and tend to lose their susceptibility as they become mature is uncertain. Little is known also as to the relation of peafowls, ducks, geese, pigeons, and various wild birds to the spread of

gapeworms. There is little question, however, that the turkey is more important than any other bird as a reservoir of infection, and it is essential, if losses from gapes are to be avoided, that the part played by the turkey in spreading and perpetuating gapeworms should be borne in mind by the poultry raiser. The relation of the turkey to gapes in chickens is commonly overlooked, largely, no doubt, because young turkeys are usually less seriously affected by gapeworms than young chickens, and because old turkeys harboring the parasites rarely show any visible evidence of infestation, so that they are not likely to be suspected as a source of the disease that plays havoc among the young chickens.

Whether, in the absence of turkeys from a farm, gapeworm disease among chickens will regularly disappear has not been definitely established, but it seems probable that it may often do so. Though it is certain that contaminated soil will remain infectious for a long time and that infection in the soil may persist from one year to the next, nevertheless it may be that, as a rule, chickens alone will not perpetuate the infection. A large proportion of the young chickens that become infested die of gapes before there has been much opportunity for scattering the eggs of the gapeworms, and since chickens as they grow older tend to become not only less susceptible to infection but also more and more unfavorable as hosts of the gapeworms acquired at an earlier age, the infested chickens that do not die of gapes probably do not continue long to harbor the worms and so are unlikely to spread much infection. In view of these apparent limitations to the reinfection of the soil by chickens it seems not unlikely that gapes will be found to have a tendency to disappear from places where no turkeys are kept.

INVESTIGATIONS ON MARYLAND FARMS.

Evidence gathered from inquiries by Dr. Lawrence Avery and the writer among poultry raisers in several localities in Maryland is insufficient to show that gapes will usually die out on farms where there are no possible hosts other than chickens, but it is corroborative of the statements that have been made as to the great importance of the turkey as a source of infection. In fact, it was found that in the absence of turkeys either no gapes occurred among the chickens or the trouble from this cause was practically always slight. On the other hand, where turkeys were present considerable losses among the chickens as a result of gapes were almost always reported. Inquiries were made on 41 farms. On 16 farms where there was no history of the association of turkeys with the chickens, gapes was reported in eight instances, no gapes in the other eight. On one farm where there were said to be numerous cases of gapes among a flock of 500 chickens, turkeys were kept the preceding

year, but it was said that they never came near the chicken yards. A dozen guinea fowls were kept on this farm and mingled with the chickens. On two other farms where there was said to be considerable trouble with gapes, guinea fowls were kept in one case, but there were neither guinea fowls nor turkeys in the other. On the other 5 farms where gapes was reported in the absence of turkeys, few cases were said to have occurred. On 25 farms where there was evidence of the contamination of the chicken runs by turkeys, gapes was reported in all but one case. Here there were about 300 chickens and 70 turkeys roaming at will over the farm. The turkeys and chickens, however, were housed on different plots of ground, neither of which had been used for poultry during several years preceding. On two farms there were said to have been no cases of gapes until after turkeys were brought to the place. In another instance a man who for five years had been on a farm where turkeys were kept by the former occupant, had gapes among his chickens for a year or two after coming to the farm, but had had none since. On two farms where only a few cases of gapes occurred among the chickens, it was stated that the turkeys were kept in the fields, and never or rarely were brought into association with the chickens. On another farm where there were a few cases of gapes no turkeys were kept, but turkeys from the neighboring farm frequented the place. In a number of other instances no turkeys were kept, but turkeys from neighboring farms were accustomed to mingle with the chickens.

Two neighboring farms that were visited during the season of the year when gapes is prevalent among young chickens afforded a striking contrast. On one farm where turkeys were kept entirely away from the chickens and never mingled with them nor came to the place where the chickens were kept there had been no gapes among the chickens. On the other farm several broods of young chickens were confined in small pens on the lawn in front of the farmhouse. Turkeys of various ages were feeding on the same lawn. Many of the young chickens were showing the characteristic symptoms of gapes.

Though the data that have been collected concerning gapes on farms are necessarily more or less inaccurate because of the uncertainty as to the reliability of the information given by the persons of whom inquiries were made, the evidence obtained from this source nevertheless indicates that in the localities in which the question has been investigated gapes is more common and more serious on farms where turkeys and chickens are kept together than on farms where only chickens are kept, that the disease has a tendency to die out in the absence of turkeys, and that it commonly does not appear on a farm until after the introduction of turkeys.

SIGNIFICANCE OF TURKEYS IN RELATION TO GAPES FORMERLY UNRECOGNIZED.

From the literature on gapes one may gather further evidence of the importance of the turkey as a carrier of gapeworms, though the peculiar significance of the turkey in relation to gapes has not been recognized by former writers. In the first published record of gapes Wiesenthal (1799) called attention to the frequent occurrence of the disease in Maryland and stated that it was most prevalent among young turkeys and chickens bred upon old-established farms. The first published record of gapes in England is that of Montagu (1811), who notes that it generally attacks chickens at the age of a month to 6 weeks, and that it "seems to be peculiar to the young of the common domestic fowl, since neither my turkeys nor ducks, all of which are reared together upon the same spot, have even been attacked."

Von Pocci (1904), in discussing an outbreak of gapes among young pheasants in Bavaria, which killed about 60 per cent of the birds, incidentally remarks that turkeys were used as brood hens for young pheasants. The first record of gapes in Norway (Horne, 1910) is based upon the discovery of gapeworms in two young turkey poults and two young chickens from the same poultry farm. How frequently turkeys have been associated with the occurrence of gapeworms among chickens, pheasants, and other birds in Europe is not indicated in the published reports that have come to the writer's attention other than those just mentioned. These, however, are very suggestive and, together with the observations recorded in the present paper, may be taken as an indication of the probability that the turkey has been chiefly, if not entirely, responsible for the spread of the gapeworm to various parts of the world.

TURKEY THE PREFERRED HOST OF THE GAPEWORM.

It would seem quite probable that the gapeworm, like the turkey, was originally limited to America and that it has reached other countries only as it has been carried by the turkey, which, because of the tolerance it has to infestation with the gapeworm, may be looked upon as the natural host of this parasite.

The fact that the gapeworm in turkeys grows to a larger size than it does in chickens may be taken as evidence, in addition to that already given, that the turkey as compared with the chicken is the preferred host of the parasite. The difference in the size of the worms may be a simple correlation with the size of the trachea, but it seems more likely that other conditions than the mere size of the trachea play a part in bringing about the differences in the size of gapeworms in chickens and turkeys. The maximum length of gape-

worms observed by the writer in chickens 14 days after infection has been 17 mm. Usually the length attained in this period is less, commonly being 12 to 14 mm. The longest gapeworm observed by the writer in chickens measured 21 mm. in length. This was found in an old, debilitated chicken, mentioned on page 6, which had been infested for an unknown period. Some of the gapeworms present in an adult turkey 19 days after infection measured nearly 30 mm. in length, and worms measuring 24 mm. were common. In natural cases of infestation gapeworms in turkeys have been found commonly to measure 30 to 40 mm. in length, and have been found as long as 50 mm. The measurements given are those of mature females that had begun oviposition or that contained eggs ready to be deposited.

HOW TO AVOID LOSSES IN CHICKENS.

From what has been determined as to the frequent occurrence of gapeworms in turkeys, the susceptibility of old as well as young turkeys to gapeworm infection, the diminishing susceptibility of chickens to infection as they grow older, and the rarity of gapeworms among adult chickens, it would seem that the chief element in the spread and maintenance of gapeworm infection, leaving infested soil out of consideration, is the turkey. The eggs of the gapeworm are scattered over the soil in the feces of infested turkeys. Later some of these eggs or the larvæ that have hatched from them are picked up again by the turkeys and more egg-producing worms develop in them to add to the number of those already present. Thus the stock of young worms in the soil and adult worms in the turkeys is maintained. Meanwhile young chickens may also pick up gapeworm eggs or larval worms from the ground where the eggs have been distributed by the turkeys, with the result that they soon show symptoms of gapes. As chickens young enough to be readily susceptible to infection with gapeworms usually die from gapes soon after they begin to show symptoms of the disease they are not likely to add much to the infection already in the soil. Older chickens likewise do not scatter much infection because the eggs and larval worms that they pick up either do not develop on account of the diminished susceptibility of the chickens or, if the worms do succeed in developing to egg-producing maturity, they are unlikely to survive for more than brief periods. Chickens, therefore, may be considered to play a small part, compared with turkeys, in infecting the soil with gapeworms, and to be of minor importance as reservoirs of infection. By keeping turkeys away from young chickens and providing the latter with runs where there have been no turkeys within a year or two and where, if used previously by young chickens, there have been no cases of gapes in recent years, the danger of losses

from gapeworm can be greatly reduced, inasmuch as infection of the runs by the brood hens is not often likely to occur because of the rarity of gapeworms among adult chickens. As the eggs and larvæ of gapeworms have been kept alive in the laboratory for more than eight months at a temperature ranging from 70° to 95° F., and for more than a year at a temperature of about 50° F. (writer's observations), it is advisable not to allow young chickens to run on once-contaminated ground until after a considerable period of time has elapsed, not less than a year at least, since its exposure to contamination. Consequently it is important in locating new runs for young chickens on farms where gapes has been prevalent to select a spot that is known to have been but little, if at all, frequented by turkeys within at least a year. Naturally also it would be unwise to select a spot where chickens with gapes had been the year before, even if in the meantime there had been no chance of contamination by turkeys. As a rule, in order easily to secure immunity from gapeworm losses among chickens, it may be found necessary to abandon the keeping of turkeys on farms where chickens are raised, because of the difficulty of controlling the turkeys so as to prevent contamination of the chicken runs. In fact the simplest way of preventing gapes among chickens seems to be to exclude turkeys from farms where chickens are raised.

CONCLUSIONS.

The turkey is probably the natural host of the gapeworm.

Adult turkeys as well as young turkeys commonly harbor gapeworms though they may show no symptoms of infestation.

The turkey is apparently the chief agent in the spread of gapeworms to new localities and is apparently the principal source of infection to the soil on poultry farms where gapes is prevalent.

Gapes among chickens appears to be more prevalent on farms where turkeys frequent the chicken runs than on farms where there are no turkeys.

Available evidence indicates that gapes has a tendency to disappear from farms following the removal of turkeys.

Chickens, unlike turkeys, are readily susceptible to infection with gapeworms only while they are young. They become less susceptible to infection as they grow older.

Adult chickens, at least in some localities, rarely harbor gapeworms and hence in such localities are seldom likely to spread infection.

In those instances in which gapeworms develop in adult chickens or chickens approaching maturity the parasites are likely to live only a short time.

Ground contaminated by gapeworms is likely to remain infective for at least a year after further infection of the soil has ceased.

Losses from gapes can be greatly reduced if not altogether avoided by keeping young chickens on ground that has not been exposed to contamination within at least a year and that is protected from further contamination by excluding turkeys from it during its occupancy by the chickens. As gapeworms appear rarely to occur in adult chickens, brood hens may be associated with the young chickens with probably little risk of infection to the latter from that source.

The simplest means of preventing or reducing losses from gapes appears to be the exclusion of turkeys from farms where chickens are raised.

LIST OF REFERENCES.

HORNE.

1910.—Fra veterinaerlaboratoriets daglige undersøkelser. En kyllingsygdom. (*Syngamus trachealis*) <Norsk Vet.-Tidsskr., Kristiania, v. 22 (6), Juni, pp. 159–164, figs. 1–2.

MONTAGU, GEORGE.

1811.—Account of a species of *Fasciola* which infests the trachea of poultry, with a mode of cure. [Read Aug. 1, 1808] <Mem. Werner Nat. Hist. Soc., Edinb. (1808–10), v. 1, pp. 194–198, pl. 7, fig. 4.

VON POCCI, FRANZ GRAF.

1904.—Der Fasan und sein gefährlichster Feind, der Rotwurm <Verhandl. d. ornith. Gesellsch. in Bayern, München (1903), v. 4, n. F., v. 1, pp. 102–118, figs. 1–3, 1 pl., figs. 1–5.

RANSOM, BRAYTON H.

1916.—Miscellaneous investigations of animal parasites <Rep. Chief Bureau Animal Indust., U. S. Dept. Agric., Wash., p. 64.

1917.—Idem <Ann. Rep. Dept. Agric., Wash. (1916), p. 130.

1917.—Miscellaneous investigations of animal parasites <Rep. Chief Bureau Animal Indust., U. S. Dept. Agric., Wash., pp. 56–58.

1918.—Idem <Ann. Rep. Dept. Agric., Washington (1917), pp. 122–124.

1918.—Miscellaneous investigations of animal parasites <Rep. Chief Bureau Animal Indust., U. S. Dept. Agric., Wash., pp. 55–56.

1919.—Idem <Ann. Rep. Dept. Agric., Wash. (1918), pp. 125–126.

1920.—On the life-history of the gape-worm (*Syngamus trachealis*). (*In* Proc. Am. Soc. Zool., 17. Ann. Meet., St. Louis, Mo., Dec. 29–31, 1919.) [Author's abstract] <Anat. Rec., Phila., v. 17 (5), Jan. 20, pp. 330–331.

1920.—Gapeworm in turkeys and chickens. [Note read before 38. Meet. Helminthol. Soc. Wash., Oct. 18, 1919] <J. Parasitol., Urbana, Ill., v. 6 (4), June, pp. 200–201. [Issued Aug. 14.]

WAITE, ROY H.

1920.—Earthworms—the important factor in the transmission of gapes in chickens <Bull. 234, Maryland Agric. Exper. Station, College Park, Jan., pp. 103–118, figs. 1–6.

WIESENTHAL, ANDREW.

1799.—[Gapes in poultry.] [Letter to editor, dated May 21, 1797] <Med. & Phys. J., Lond., v. 2 (8), Oct., pp. 204–205, 2 figs.

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THE SPOROGENES TEST AS AN INDEX OF THE CONTAMINATION OF MILK.

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PRESENT STATUS OF THE SPOROGENES TEST.

The sporogenes test is based on the characteristic milk reaction produced by certain anaërobic spore-forming bacteria which are widely distributed in nature and which are particularly common in fecal material.

Numerous names have been given to anaërobic bacteria that give the typical milk reaction, some of which are the following: *B. enteritidis sporogenes* (Klein); *B. aerogenes capsulatus* (Welch), synonym *B. welchii* (Migula); *B. perfringens* (Veillon and Zuber); and *B. Saccharobutyricus immobilis* (Schattenfroh and Grassberger). It is generally believed that the organisms bearing these names are either identical or very closely related species.

In milk, under anaërobic conditions, these organisms produce what is known as the "stormy" fermentation. In a characteristic reaction the casein is coagulated and the curd torn by gas within 24 hours at 37° C. The whey is usually quite clear and the odor of butyric acid is noticeable. When the milk in a test tube is covered with a paraffin plug the latter is usually forced up almost to the top of the tube and sometimes entirely out of the tube.

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English bacteriologists have made use of this characteristic reaction, both in water and milk analysis, in order to detect the presence of *B. enteritidis sporogenes*, which in their opinion indicates contamination by fecal material. The test has consequently become known as the sporogenes test. Therefore, in this paper the name *B. enteritidis sporogenes* will be used in designating the organism causing the stormy reaction, except when direct reference is made to publications in which different terms are used. The organisms giving this test should not be confused with *B. sporogenes* of Metchnikoff, which gives an entirely different milk reaction.

Whether the bacteria which show the sporogenes test are identical makes little difference provided their distribution in nature is about the same. They are known to be present in fecal material, in miscellaneous foodstuffs, cattle feed, soil, and water. Since they are present in cow feces, it is natural to assume that their presence in milk may be used as an index of contamination by manure. If they are present in feeds and soil to the same extent as in manure, their presence in milk may be rather an index of the general condition of cleanliness of production.

The obvious advantage of using the spores of *B. enteritidis sporogenes* as an index of contamination lies in the fact that pasteurization does not destroy them, and therefore does not interfere with the determination of their presence in milk. Furthermore, they are not believed to vegetate in milk under normal conditions, and vegetative cells do not sporulate in the presence of the fermentable sugar in milk; so the sporogenes test with both fresh and old milk, provided it is still sweet, should give the same results. The test has consequently become known as a "nonmultiplying test." Should it prove to be reliable in gauging the cleanliness of production and be relatively accurate, it would be extremely valuable in milk-control work.

It has not been difficult to find spores in milk which give the characteristic stormy reaction. Flügge (4)[1] in 1894 isolated anaërobic butyric-acid bacteria from milk. In 1897 Klein (8) examined milk in London for spores of *B. enteritidis sporogenes* and found them in 8 of the 10 samples examined. Since then they have been found in milk by various investigators, among whom are Savage (12), Houston (7), Barthel (1), Brown (2), Simonds (14), Ritchie (11), Pryor (9), Weinzirl (15), Shippen (13), and Ford (5). Probably spores of these anaërobic bacteria can be found in all milk if large enough amounts are examined.

There seems to be a difference of opinion among different investigators as to the value of the sporogenes test in indicating manurial contamination and the general conditions of cleanliness in produc-

[1] The numbers in parentheses refer to "Literature cited," at end of bulletin.

tion. Savage (12), who was among the first to apply the test for this purpose, and who has studied the test probably more than any one else, realized its limitations. He states that the test does not show so close an agreement with the cleanliness of farm conditions as does the estimation of *B. coli.* On the whole, however, he thought that the sporogenes test might be of considerable value in estimating pollution, especially in market milk. Ritchie (11) concluded from his results that the sporogenes test was of little value. He obtained no correlation between the number of positive reactions and farm conditions. Barthel (1) was of the opinion that there never was a direct relation between the hygienic quality of milk and the presence of strict anaërobes. On the other hand, Weinzirl and Veldee (15) have used the test as a means of determining the manurial pollution of milk and believe it to be of distinct value.

There is nothing new about the sporogenes test so far as its general application is concerned. It has been known for a long time, but it has not been given a thorough trial under controlled conditions of production. From past results the test gives promise of being too valuable to discard, yet it is too uncertain at present to use without knowing its limitations.

It is the purpose of this paper to present some results obtained with the sporogenes test on milk produced under controlled conditions.

THE SAVAGE METHOD.

Savage (12) first examined 1 c. c., 10 c. c., and 20 c. c. of milk, the smallest quantity being added to a tube of freshly sterilized whole milk, while the other quantities were placed in empty, sterile test tubes. The milk was heated to 80° C. for 10 minutes, then cooled and incubated under anaërobic conditions at 37° C. After 48 hours the tubes were examined for the typical stormy reaction. These quantities were found to be too wide apart to yield a satisfactory estimation of the number of spores, so the following method was advocated. Small, narrow tubes, about 4 inches by ¼ inch, were used in batches of 10. The tubes were sterilized and 2 c. c. of milk added to each, making a total of 20 c. c. in the 10 tubes. The tubes were heated, incubated, and examined as mentioned above. Each tube which showed a typical stormy reaction was recorded as 1. Thus, if three tubes showed the reaction, the result was recorded as 3.

Savage set the following arbitrary standard, which he says can not be considered a rigid standard:

0 or 1 tube positive=good milk.

2, 3, or 4 tubes positive=unsatisfactory milk.

5 or more tubes positive=bad milk.

A number of samples of milk produced under dirty conditions have been examined by the Savage 10-tube method. His method was

varied slightly in that sterile paraffin was poured into each tube after heating. This formed a plug over the milk, and it was not necessary to place the tubes under anaërobic conditions.

It was considered advisable to try the test on milk produced under conditions that would represent the worst grade of milk which might be encountered under commercial conditions. In order to do this, four cows were placed in a small barn which had been used for similar experimental purposes. The loft above the cows was composed of narrow boards laid from 1 to 2 inches apart. Hay and cobwebs hung down from these openings. The walls were soiled with manure and dirt. All the cows were allowed to become dirty and their udders and flanks were more or less covered with partly dried manure. The manure was removed from the floor only twice a week. Open pails, not sterilized, were used for milking.

To show the relation between the Savage sporogenes test and the milk, the sediment from 1 pint of milk, the total count, and the result of the Savage test are shown in Plates I, II, and III. In the upper right-hand corner of each square is a number designating the number of tubes showing a positive sporogenes test out of the 10 tubes used for each sample. Keeping in mind the arbitrary standards set by Savage (that is, 0 or 1 + = good milk, 2, 3, or 4 + = unsatisfactory milk, 5 or more + = bad milk) the results are interesting. It will be noted that according to this test the milk from Samples 1 to 35, inclusive, would be called good milk. It is believed that the sediment disks and counts make further discussion unnecessary. Particular attention is called to the difference in sediment between Sample 1 and Samples 19 and 20. None of the three showed a positive test by the Savage method. On Plate III samples from 36 to 52, inclusive, would be classed as unsatisfactory by the Savage sporogenes test. No one would dispute this statement, although many were no worse than those called good on Plates I and II. Samples 53, 54, and 55 are classed as bad by the test, yet they are no worse than some called good.

It is further evident from the results shown on the plates that there is no relation between the sporogenes test as used by Savage and the total count. In this connection it may be noted that the milk examined was fresh milk. Savage also found very little relationship between the test and the total count.

The question naturally arises in connection with the sporogenes test as to the accuracy of the test itself. Will a number of tests with a given sample of milk show the same results? To answer this question, 5 sets of 10 tubes each, with 2 c. c. of milk in each tube, were prepared from a sample of milk. In other words, the Savage method was applied 5 times to the same sample of milk. From the results of

14 samples of milk examined in this manner it is evident as shown in Table 1 that there may be a considerable variation in the results obtained from a given sample.

TABLE 1.—*Variation in the Savage sporogenes test, showing number of positive tubes of 2 c. c. each after incubating for 48 hours at 37° to 40° C.*

Sample.	Number of positive tests.					Range in number of positive tests.
	Set 1.	Set 2.	Set 3.	Set 4.	Set 5.	
1	3	5	6	3	2	2 to 6
2	4	0	2	1	3	0 to 4
3	2	2	1	0	2	0 to 2
4	1	1	1	0	0	0 to 1
5	1	0	0	1	1	0 to 1
6	1	2	0	1	2	0 to 2
7	2	1	2	2	1	1 to 2
8	1	2	2	0	2	0 to 2
9	1	0	0	0	0	0 to 1
10	4	4	1	3	3	1 to 4
11	9	8	5	6	7	5 to 9
12	6	8	5	6	6	5 to 8
13	7	6	3	7	6	3 to 7
14	9	8	9	7	9	7 to 9

The sample of milk in every case was shaken thoroughly to give as equal a distribution of spores as possible. The 2 c. c. samples used in the sporogenes test were removed in two different ways: (1) Ten 2 c. c. samples were removed from the sample of milk by means of a sterile 2 c. c. pipette; (2) ten 2 c. c. samples were removed from the sample of milk by means of a sterile 10 c. c. graduated pipette, successive 2 c. c. portions being delivered for each sample. It was found that this variation in removal of the 2 c. c. samples had no effect on the results of the sporogenes test.

The effect of the variations in the numbers of positive tubes and different sets of tubes of milk from the same sample of milk is obvious when one attempts to grade the milk by the Savage method. For example, in Table 1, Samples 2, 3, 6, 8, and 10 would be graded as either *good* or *unsatisfactory*, according to the results of the sporogenes test and the Savage arbitrary standards. This is shown more clearly by consideration of the results obtained with Sample 2. Each set of 10 tubes represents a complete sporogenes test according to the Savage method. In Set 2 there were no positive tests and in Set 4 there was one; therefore, the milk would be graded by either of these tests as good. In the other sets there were 2, 3, and 4 tubes positive, which according to the standards would necessitate calling the milk unsatisfactory.

Two reasons at least may be designated as contributing causes for the variations in the sporogenes test: First, uneven distribution of the spores in the milk; and, second, lack of development of the characteristic stormy reaction on which the test is based. Savage (12) mentions the fact that the lack of an even distribution of spores is a

serious drawback to the utility of the test, while Simonds (14) found that a failure to get the stormy fermentation does not necessarily mean a lack of growth of the organisms giving the test. This he believes from his experiments is due to not having the correct degree of anaërobiosis in the milk tubes.

How far the lack of development of the characteristic stormy reaction influences the assumption of an unequal distribution of spores is difficult to determine. As long as these variations in the sporogenes tests continue, the value of the test is materially lowered, and the reason for the variation is of little importance except that if it were definitely known some remedy might be found. This defect in the sporogenes test applies not only to the Savage method but also to the other methods mentioned in this paper.

THE WEINZIRL METHOD.

A method of determining manurial pollution of milk in which the sporogenes test is used has been suggested by Weinzirl (15). The method of making the test is essentially the same as the first one used by Savage, although the results were interpreted in a somewhat different manner. The method of Weinzirl consists in using 5, 10, and 15 c. c. samples of milk from each sample which is to be examined. The milk is heated to 80° C. for 10 minutes and melted paraffin poured on the milk to make a layer one-eighth inch or more in thickness. The tubes of milk are then cooled and incubated at 37° C. From his examination of cow manure, Weinzirl calculated that there were probably 10,000 sporogenes per gram of manure in the partially dried condition in which it usually enters milk. Based on this figure, he estimated the amount of manure in milk as follows: A positive reaction in the 5 c. c. tube indicates 1 gram of manure in 50 liters of milk; a positive reaction in the 10 c. c. tube indicates 1 gram of manure in 100 liters of milk; and a positive reaction in a 15 c. c. tube indicates 1 gram of manure in 150 liters of milk.

To determine the value of Weinzirl's method, 48 samples of milk were examined which were produced under dirty conditions. The same conditions of production prevailed as those previously described under the Savage test. The results of the work are presented in Plates IV and V, on which are shown sediment disks from each pint sample of milk examined, together with the results of the sporogenes test as performed by Weinzirl and the total bacterial count. Fresh milk was examined in all cases. In the upper left-hand corner of each square is shown the result of the sporogenes test. Figures 5, 10, and 15 represent the respective number of cubic centimeters of milk used, and opposite each is a positive or negative sign. A positive sign indicates a "stormy" fermentation, and a negative sign the absence of the characteristic reaction.

In order to show the value of the Weinzirl test, the samples of milk have been grouped on the basis of the test in accordance with his arbitrarily assumed standards. Weinzirl's standards were as follows: One gram of manure in 50 liters of milk is excessive; not more than 1 gram in 100 liters of milk is fair; and not more than 1 gram in 150 liters represents good market milk.

On the basis of this classification, all the samples represented by sediment disks in Plate IV would be classed as good milk. Undoubtedly such a classification is incorrect. Particular attention is called to the differences in the quantity of manure among samples showing the same results with this sporogenes test. Compare, for example, Samples 1 and 15. In neither case were any positive reactions recorded.

The sediment disks on Plate V were made from milk which would be classed as fair or as having an excessive quantity of manure, according to Weinzirl. The last three samples are the only ones which would be considered to have an excessive amount of manure. It is evident that, with the exception of Sample 36, the rest of the samples at least do not represent good milk, and are certainly no better than the fair milk as classified by the Weinzirl test. Many of these samples of so-called fair milk, however, were evidently much better than some of those classed as good milk.

As in the Savage method, there is also no definite relation between the Weinzirl sporogenes test and the total bacterial count. Particular attention is called to the variation between the test and the amount of sediment. This is especially striking in the case of Samples 15 on Plate IV and 36 on Plate V. Sample 15 had an excessive quantity of manure showing a negative sporogenes test, while Sample 36 had a small amount of sediment and yet gave a positive reaction in the 5 c. c. tube. Positive tests among the three quantities of milk used seem to show no consistent behavior. If a sufficient number of spores are present in the milk to give a positive test in the 5 c. c. tube, the 10 and 15 c. c. tubes should also be positive. If the 10 c. c. tube is positive, the 15 c. c. tube should also show the reaction, but such is not always the case. These variations probably are due either to an uneven distribution of spores or to their failure to develop a characteristic stormy reaction. Weinzirl, of course, merely assumed an arbitrary standard for grading milk on the basis of the sporogenes test, but whatever standard is accepted it would not change the lack of correlation between his methods of making the sporogenes test and the quantity of manure actually in the sample.

DEFECTS IN THE SPOROGENES TEST.

Besides the variations in results obtained by repeating the sporogenes test on the same samples of milk, the test is defective because it

is not positively known how the spores of the organisms giving the test gain entrance to milk. This fact naturally decreases the utility of the test. Savage recognizes this condition of affairs, and in weighing the value of the test rightly assumes that they might gain entrance to milk from other sources, and thus would represent contamination by material not so undesirable as manure.

Weinzirl seems to have overlooked the possibility of the entrance of the spores of *B. enteritidis sporogenes* from sources other than cow manure. He makes a further assumption, which from our results seems to be incorrect—that of giving an average figure which can be safely set up as being the number of spores per gram of manure. He estimates that cow manure as it enters milk contains the probable average of 10,000 spores per gram. He found that in moist cow manure there may be fewer than 730 or more than 14,300 per gram. This is a decidedly higher figure than was obtained by Savage, who estimated from 10 to 10,000 per gram. As is shown in Table 2, our figures for the number of spores of *B. enteritidis sporogenes* in cow feces are much lower than those obtained by Weinzirl, and agree closely with the results of Savage. In fact, our figures, on the whole, are even lower than those of Savage. The manure examined consisted of samples ranging from fresh to nearly air dry, the most of them, however, being decidedly moist.

TABLE 2.—*Number of spores of B. enteritidis sporogenes in cow manure and feed.*

Sample No.	Cow feces.	Feed.		Sample No.	Cow feces.	Feed.	
		Silage.	Grain.			Silage.	Grain.
	Spores per gram.	*Spores per gram.*	*Spores per gram.*		*Spores per gram.*	*Spores per gram.*	*Spores per gram.*
1	40	60	.....	13	140	.....	30
2	50	[1] 0	.....	14	100	.....	20
3	200	400	.....	15	140	.....	40
4	600	800	.....	16	600	.....	35
5	20	20	.....	17	20	.....	[1] 0
6	50	55	.....	18	240	.....	15
7	600	30	.....	19	40	.....	20
8	60	15	.....	20	20	.....	30
9	800	80	.....	21	20	.....	100
10	1,000	40	.....	22	140	.....	20
11	800	60	.....	23	.....	.....	40
12	1,000	80	.....	24	.....	.....	200

[1] 0–$\frac{1}{10}$ gram.

The average spore content of 22 samples representing different cows from herds in widely scattered parts of the country was estimated to be 304 per gram. The number of spores was estimated by inoculating several series of 5 tubes of sterile milk each with a different dilution of manure in sterile water. The tubes were then heated to 80° C. for 10 minutes, then cooled and incubated. From

the number of stormy reactions and the dilution the number of spores in the manure was estimated. Assuming that the manure as it enters milk contains only one-fourth as much moisture as samples of moist feces, and multiplying, therefore, the average spore content by four, it may be assumed from the results that the manure as it enters the milk contains approximately 1,200 spores per gram. When this average figure is compared with the 10,000 obtained by Weinzirl it is apparent that there must be an extremely variable number of spores of *B. enteritidis sporogenes* in cow feces. Even if it were possible to assume that these spores could gain entrance into milk from cow manure only (without definite proof this assumption can not safely be made) their variable number in this material would decidedly interfere with the accuracy of the test. In the light of these facts it is probably possible to explain the discrepancies that exist between the test and the manurial content of the milk.

Spores of the organism under consideration are known to be widely distributed in nature. They are found in waters and soils, and, as is shown in Table 2, they are present in considerable numbers in silage, grain, and mixed feeds. How many spores may gain entrance into milk from these sources is of course problematical, although on the whole it seems probable that they are introduced in the greatest numbers through manure.

It seems apparent from the results of other investigations and of our experiments that if the sporogenes test is to be of any definite value its greatest possibility lies in the relation which the test bears to the general conditions of production.

ATTEMPTS TO IMPROVE THE CHARACTERISTIC STORMY REACTION.

Before going further with the sporogenes test it was considered desirable (1) to reduce if possible the number of doubtful reactions caused by peptonizing faculative anaërobes and (2) to hasten and make more dominant the growth of *B. enteritidis sporogenes* by adding to milk certain substances likely to promote more rapid growth of the organism.

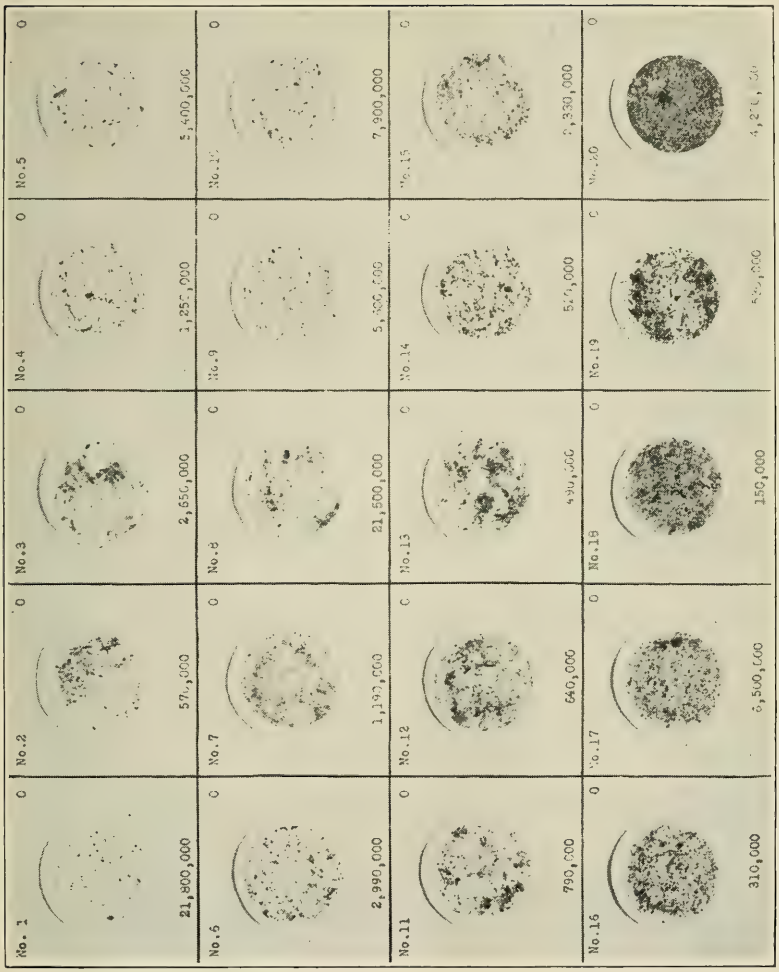
To eliminate peptonization, attempts were made to utilize the selective action of gentian violet. Churchman (3) has shown that gentian violet in a dilution of 1 to 100,000 of medium prevented the growth of *B. subtilis* while it permitted the growth of *B. welchii*. Dilutions of 1 to 50,000 and 1 to 100,000 were tried, the necessary amount of a stock solution of 1 to 1,000 being added previous to heating the milk tubes. It was found that the proportions of 1 to 50,000

largely eliminated peptonization and made the stormy reaction more clear-cut, but at the same time reduced the number of positive tests, probably because of an inhibiting action on *B. enteritidis sporogenes*. With a strength of 1 to 100,000 the gentian violet caused no reduction in the number of positive tests, but also had no effect in eliminating peptonization in samples containing facultative anaërobes capable of producing this reaction. While peptonization in occasional tubes is not a very serious matter, it tends to create difficulty in determining whether a tube shows a typical stormy fermentation. The use of gentian violet proved to be of no assistance in this connection.

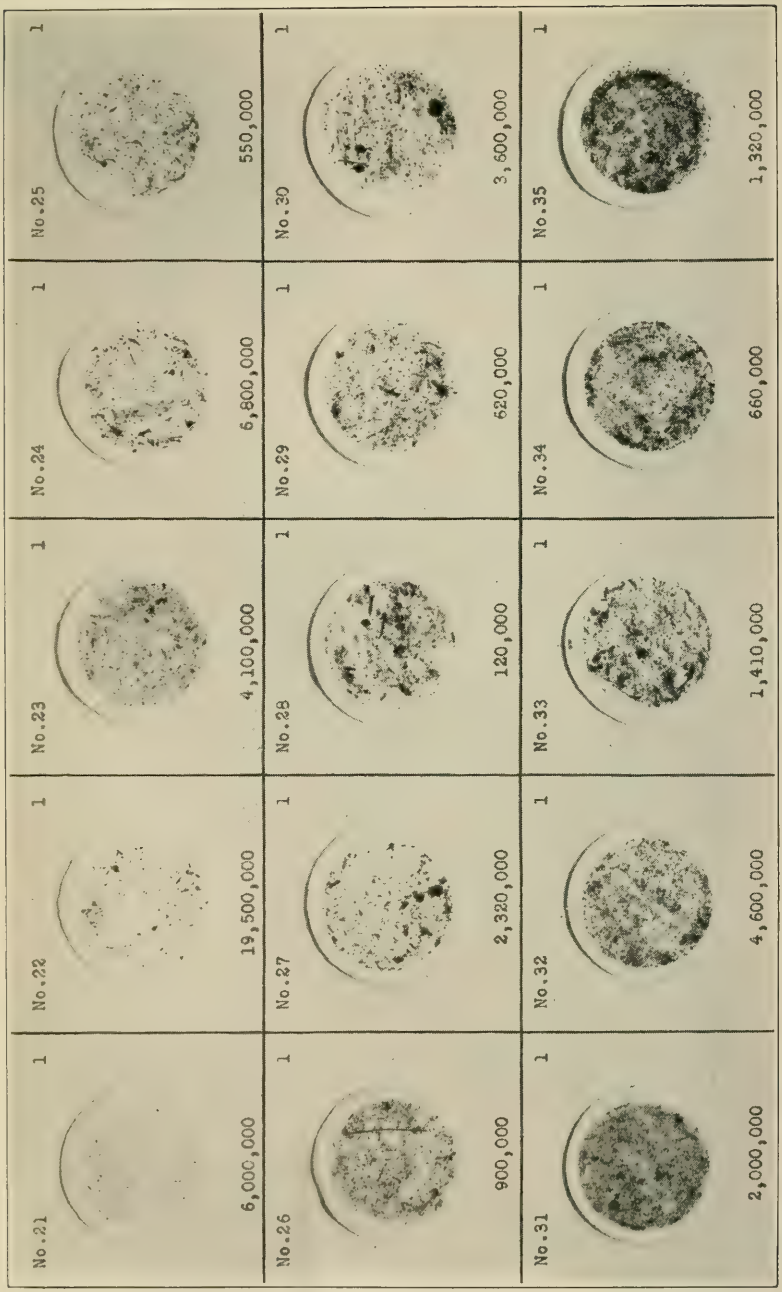
Henry (6) made use of alkaline egg albumen in connection with the development of *B. welchii* on solid media and obtained beneficial results. It was thought, therefore, that it might be possible to use this in connection with the sporogenes test in order to stimulate the growth of these organisms. The alkaline egg medium as given by Henry is as follows:

To the whites of two eggs 4 c. c. of N/1 NaOH is added and the mixture heated at about 95° C. for 1½ hours. Solution is then made up to 330 c. c. volume with water and then filtered and sterilized. When using the sporogenes test with 10 tubes of 2 c. c. each of milk, 1 c. c. of sterile, alkaline egg solution was added to each tube before the milk. The tubes were then heated and carried through the test in the usual manner. In some samples of milk it was found that when alkaline egg was used the number of positive tubes in the set of 10 was considerably increased. Quite often the reaction appeared more quickly than in the tubes without the egg solution and as a rule the reaction was more vigorous. This likely improvement in the test did not follow consistently, however, in all samples, and it was found that the advantage gained did not compensate for the additional trouble of using the alkaline egg solution.

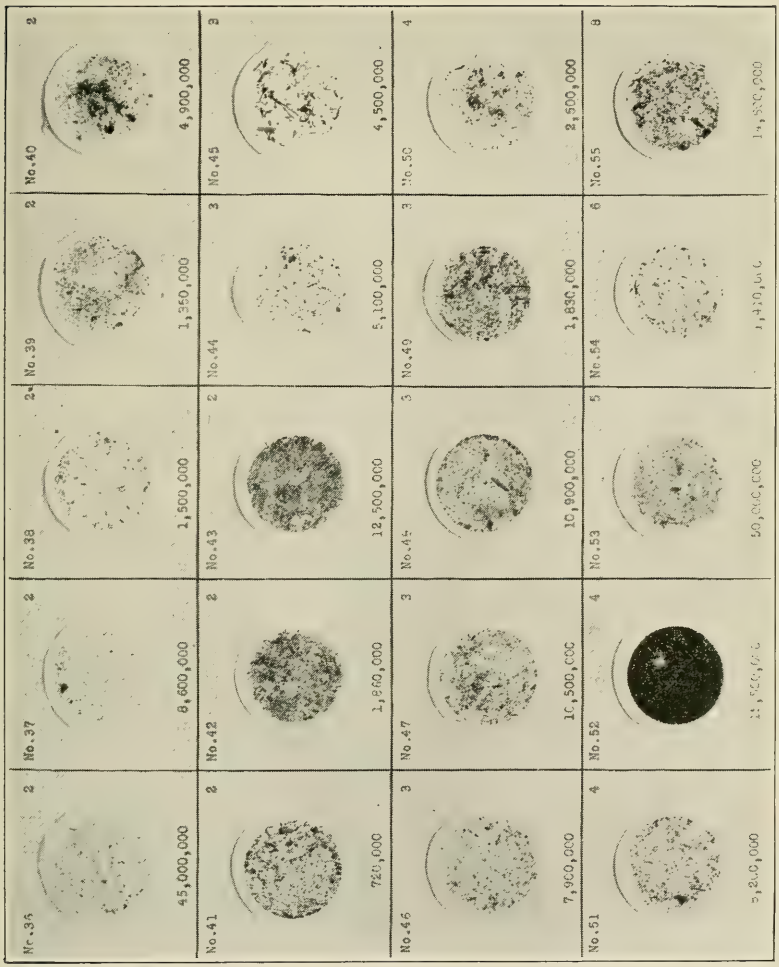
The effect of the addition of peptone on the sporogenes test was also tried. In this experiment 10 tubes, each containing 10 c. c. of milk, were used instead of the 2 c. c. amounts used by Savage. Two series of tubes of 10 c. c. each were prepared, one series containing approximately 5 per cent peptone and the other containing none. One c. c. of a sterile 5 per cent solution of peptone was placed in each tube of the peptone series, to each of which was then added 10 c. c. of milk. Nineteen samples of milk were examined on this comparative basis and the results indicated that in some cases the addition of peptone caused an increase in the number of positive tubes and also a more vigorous reaction. In other samples the number of positive reactions was lower in the milk with peptone than in that without. On the whole, the results indicated that there was no particular advantage in the addition of the peptone solution.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER DIRTY CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS WITH SAVAGE'S SPOROGENES TEST AND THE TOTAL COUNT.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER DIRTY CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS WITH SAVAGE'S SPOROGENES TEST AND THE TOTAL COUNT.



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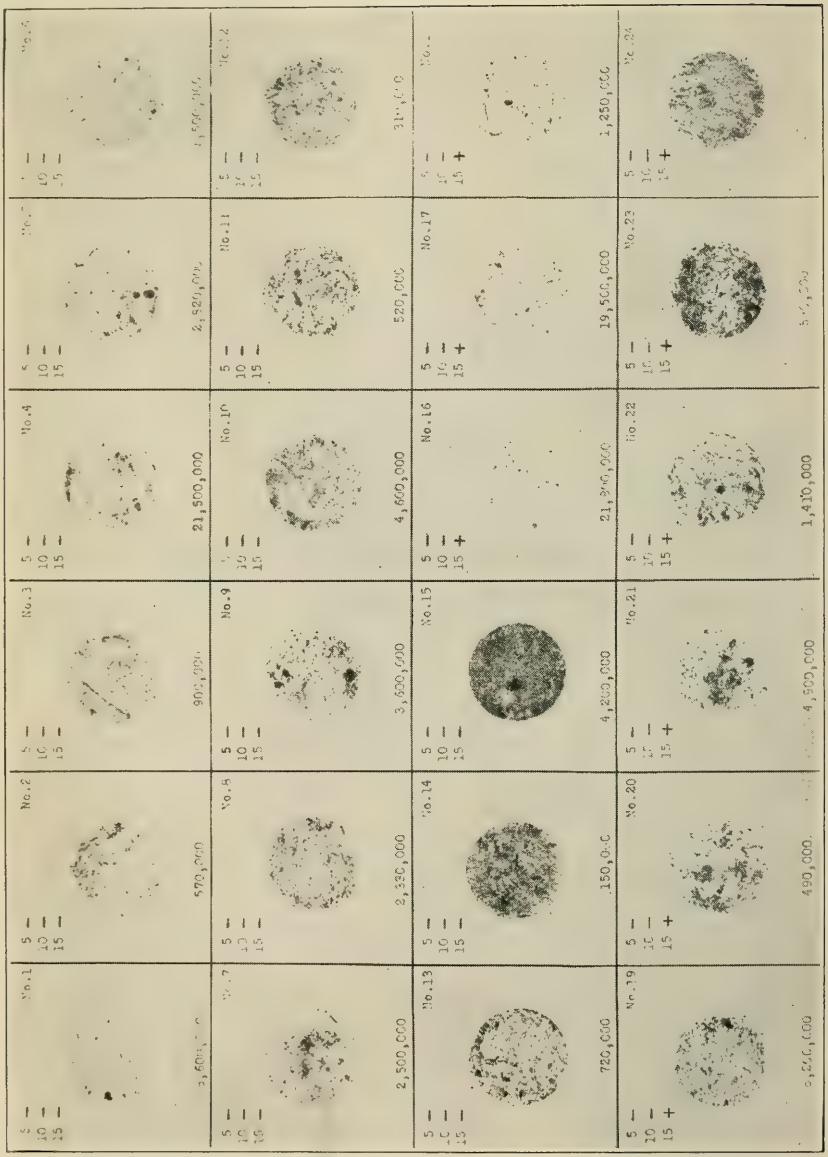
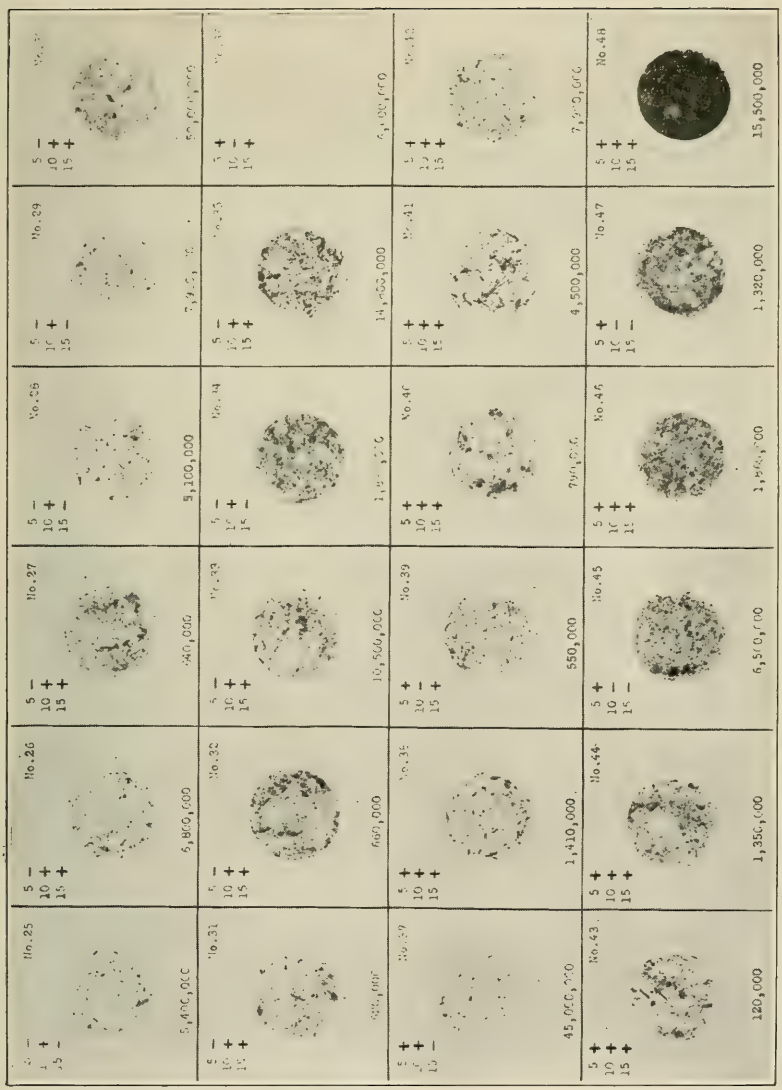
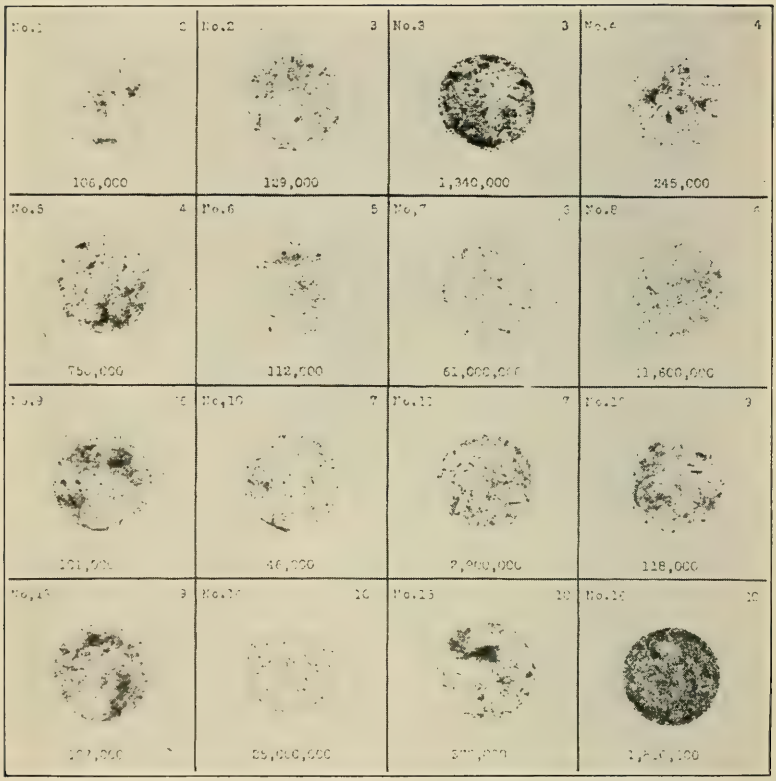


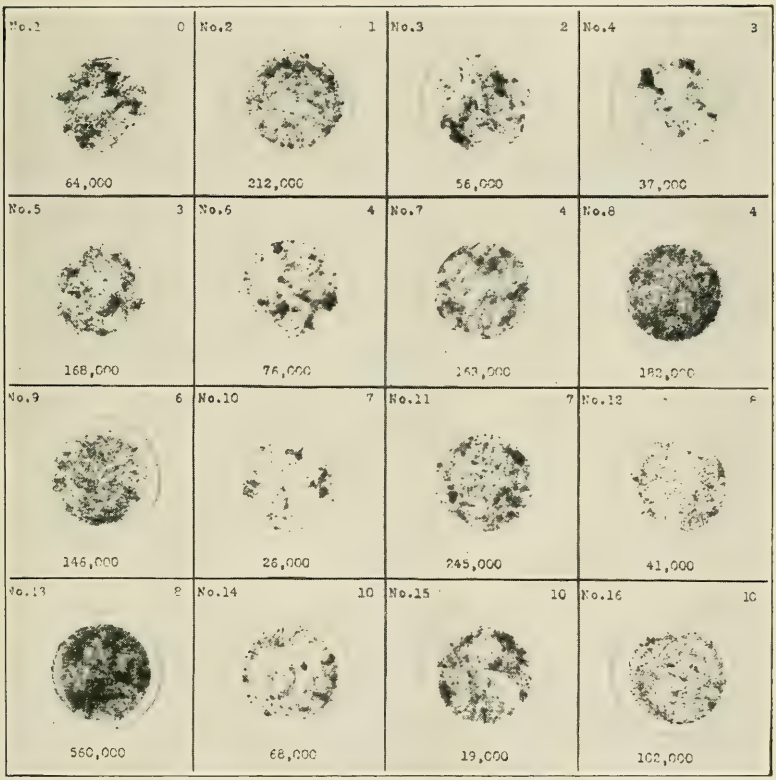
SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER DIRTY CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS WITH WEINZIRL'S SPOROGENES TEST AND THE TOTAL COUNT.



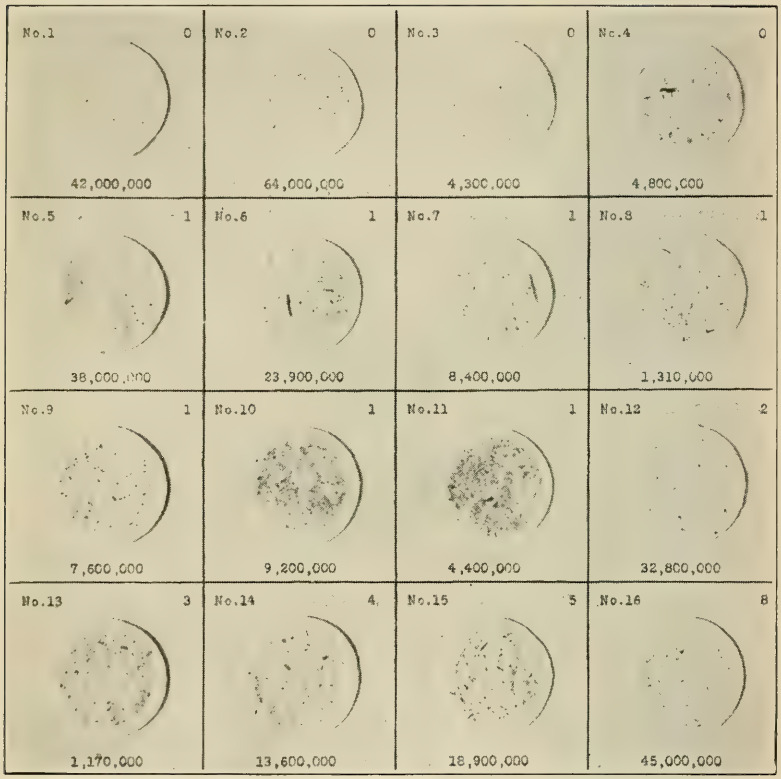
SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER DIRTY CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS WITH WEINZIRL'S SPOROGENES TEST AND THE TOTAL COUNT.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER DIRTY CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS OF SPOROGENES TEST AND TOTAL COUNT.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER DIRTY CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS OF THE SPOROGENES TEST AND THE TOTAL COUNTS.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED UNDER CLEAN CONDITIONS, WITH UTENSILS NOT STERILIZED, SHOWING RESULTS OF THE SPOROGENES TEST AND THE TOTAL COUNTS.

USE OF 20 C. C. AMOUNTS OF MILK IN THE SPOROGENES TEST.

While working with the Savage test where 2 c. c. amounts of milk were used in 10 tubes, it seemed apparent that if the test was to be used in the most efficient manner its range would have to be increased so as to allow a greater difference, if possible, between good and bad milk. It seemed probable that this might be accomplished by using 10 c. c. or 20 c. c. quantities of milk.

A series of tests was therefore made, using 2 c. c., 10 c. c., and 20 c. c. of milk, produced under the dirty conditions previously described. The results in Table 3 show clearly the value of larger samples of milk. They are arranged in the order of the number of positive reactions in the 2 c. c. samples, and the corresponding results with 10 and 20 c. c. are placed opposite. It should be kept in mind that all the milk examined was produced under extremely dirty conditions and contained an abnormal quantity of manure in many cases. In other words, the milk represented the worst grade that would ever be encountered in commercial conditions.

TABLE 3.—*Comparison of number of positive reactions when different quantities of milk were used.*

Sample No.	Sets of 10 tubes, 2 c. c. each.										Sets of 10 tubes, 10 c. c. each.										Sets of 10 tubes, 20 c. c. each.									
1	−	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−
2	−	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	+	+	+	+	+	−	−	−	−	−
3	−	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+	+	+	−
4	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−
5	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−
6	−	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−
7	−	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	+	+	−	−	−	−	−	−
8	−	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−
9	+	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	−	−	−	−	+	+	+	+	+	+	+	−	−	−
10	+	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−
11	+	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	+	+	−	−	−	−	−	−
12	+	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−
13	+	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−
14	+	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−
15	+	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+	−	−	+	+	+	+	+	+	+	−	−	−
16	+	−	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	+	+	+	+	−	−	−	−	−	−
17	+	+	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+	+	+	−
18	+	+	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+	−	−	−
19	+	+	−	−	−	−	−	−	−	−	+	+	+	+	−	−	−	−	−	−	+	+	+	+	−	−	−	−	−	−
20	+	+	+	−	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+	−	−	−
21	+	+	+	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	+	+	+	+	+	+	−	−	−	−
22	+	+	+	+	−	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	−	−	−	−
23	+	+	+	+	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+	+	+	+	−	−
24	+	+	+	+	+	−	−	−	−	−	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+	+	+	+	+	+
25	+	+	+	+	+	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	−	−	−	−	−	−
26	+	+	+	+	+	−	−	−	−	−	+	+	+	+	+	+	+	+	−	−	+	+	+	+	+	+	+	+	−	−
27	+	+	+	+	+	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+	+	+	−
28	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+	+	+	+	+
29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Keeping this fact in mind, it is interesting to observe that more than one-half of the samples in which 2 c. c. of milk were used showed either none or only one positive reaction. The first 8 samples showing no positive reactions could not be differentiated by means

of this test from the highest grade of milk that could be produced. The results with the 10 c c. amount of milk were not found to be so satisfactory as the 20 c. c., because during the examination of certified milk a positive test was rarely encountered with the smaller amount.

It was felt that an amount of milk should be used which if possible would show at least one positive reaction in a set of 10 tubes with milk produced under the cleanest conditions, and would show also a large number of positive reactions with milk produced under extremely dirty conditions. The results in Table 3 show that 2 c. c. amounts of milk do not meet this requirement, for with dirty milk 8 out of 30 samples gave no positive sporogenes test. In the same dirty milk there was a greater tendency for a larger number of the 10 tubes with 20 c. c. each to show the characteristic stormy reaction. Even with the 20 c. c. quantities the results were not so uniformly high as could be desired, but this amount of milk possessed the added advantage of being about the smallest amount which could be used to show positive reactions in milk produced under the cleanest conditions.

THE SPOROGENES TEST IN RELATION TO MILK PRODUCED UNDER EXTREME CONDITIONS OF CLEANLINESS AND OF FILTH.

It was evident that if the sporogenes test could not differentiate between samples of milk produced under clean and dirty conditions there could be no hope of the test's being of value in milk-control work. To determine this point the sporogenes test, using 10 tubes with 20 c. c. of milk, was applied to 24 samples of certified milk and 18 samples of milk produced under the dirty conditions previously described. The results in Table 4 show that the test with 20 c. c. of milk to each tube can be used with milk produced under extremes in conditions. About 50 per cent of the samples of certified milk showed no positive reaction, but of the remaining 13 samples 7 showed 1 positive tube, 5 showed 2 positive, and 1 showed 4 positive.

TABLE 4.—*The sporogenes test with milk produced under clean and under dirty conditions.*

CERTIFIED MILK.

Sample No.	Sporogenes test in sets of 10 tubes, with 20 c. c. of milk.										Positive tests.	Bacterial count.
1	+	+	−	−	−	−	−	−	−	−	2	3,900
2	+	+	−	−	−	−	−	−	−	−	2	4,400
3	−	−	−	−	−	−	−	−	−	−	0	4,600
4	+	−	−	−	−	−	−	−	−	−	1	6,500
5	−	−	−	−	−	−	−	−	−	−	0	8,200
6	−	−	−	−	−	−	−	−	−	−	0	8,600
7	−	−	−	−	−	−	−	−	−	−	0	8,100
8	−	−	−	−	−	−	−	−	−	−	0	9,900
9	+	−	−	−	−	−	−	−	−	−	1	10,300
10	+	+	+	+	−	−	−	−	−	−	4	10,500
11	+	+	−	−	−	−	−	−	−	−	2	10,500
12	+	−	−	−	−	−	−	−	−	−	1	11,000
13	+	−	−	−	−	−	−	−	−	−	1	12,200
14	+	−	−	−	−	−	−	−	−	−	1	12,600
15	−	−	−	−	−	−	−	−	−	−	0	12,700
16	+	+	−	−	−	−	−	−	−	−	2	16,700
17	−	−	−	−	−	−	−	−	−	−	0	18,000
18	+	−	−	−	−	−	−	−	−	−	1	20,700
19	−	−	−	−	−	−	−	−	−	−	0	28,400
20	−	−	−	−	−	−	−	−	−	−	0	31,500
21	−	−	−	−	−	−	−	−	−	−	0	31,800
22	−	−	−	−	−	−	−	−	−	−	0	36,600
23	+	−	−	−	−	−	−	−	−	−	1	40,700
24	+	+	−	−	−	−	−	−	−	−	2	45,000

MILK PRODUCED UNDER DIRTY CONDITIONS; COWS DIRTY; UTENSILS NOT STERILIZED.

1	+	+	+	+	+	+	+	+	+	−	9	33,000
2	+	+	+	+	+	+	+	−	−	−	7	46,000
3	+	+	+	+	+	+	−	−	−	−	6	101,000
4	+	+	−	−	−	−	−	−	−	−	2	106,000
5	+	+	+	+	+	+	+	+	+	−	9	107,000
6	+	+	+	+	+	−	−	−	−	−	5	112,000
7	+	+	+	+	+	+	+	+	+	−	9	118,000
8	+	+	+	−	−	−	−	−	−	−	3	129,000
9	+	+	+	+	−	−	−	−	−	−	4	245,000
10	+	+	+	+	+	+	+	+	+	+	10	320,000
11	+	+	+	+	−	−	−	−	−	−	4	750,000
12	+	+	+	−	−	−	−	−	−	−	3	1,340,000
13	+	+	+	+	+	+	+	+	+	+	10	1,810,000
14	+	+	+	+	+	+	+	−	−	−	7	2,900,000
15	+	+	+	+	+	+	−	−	−	−	6	11,600,000
16	+	+	+	+	+	+	+	−	−	−	7	22,500,000
17	+	+	+	+	+	+	+	+	+	+	10	25,000,000
18	+	+	+	+	+	+	−	−	−	−	6	61,000,000

An examination of the results obtained from milk produced under extremely dirty conditions shows that in general the number of positive tubes was considerably higher than in the case of the certified milk. It is true that there were some samples which showed only two or three positive results. Such samples would be difficult to place by this test. The general picture presented by the results, however, is such that a marked difference is shown in the results obtained by the sporogenes test when milk is examined which has been produced under these extreme conditions. It is evident that these results determine the limitations of the test. The number of positive reactions in a set of 10 tubes using 20 c. c. quantities of milk, therefore, must fall either within the range of the results shown in Table 4, which represent the examination of good and bad milk, or somewhere between these fig-

ures. It is apparent that there is not a very great range left to cover the results obtained in the examination of the intermediate grades of milk. From these results, however, it seems probable that the sporogenes test, using 10 tubes of 20 c. c. quantities of milk for each tube, may be of some value in determining whether milk has been produced under clean or dirty conditions. One test, however, would probably not be sufficient to enable one to make this decision. If several tests were made and the great majority of the results were either high or low, the results could be interpreted more accurately and the value of the test would be greatly improved.

It is impossible to say from these results where milk produced under fair conditions would fall according to this grouping. The tendency would be for such samples to show great variations, some falling into the clean grade, others into the dirty grade.

CONDITIONS OF PRODUCTION OF PASTEURIZED MILK AS INDICATED BY THE SPOROGENES TEST.

In connection with the results just discussed it will be of interest to see what commercially pasteurized milk showed, using this test to indicate conditions of production. This is possible, because the test is probably a nonmultiplying one, as shown by the work of Savage (12). To verify this point several experiments were conducted by holding pasteurized milk at room temperature for 24 hours. No change in the number of spores was observed other than what could be accounted for by the limitations of the test.

Since the spores are not destroyed by the usual pasteurizing temperatures and do not change in number, the sporogenes test, if it correlates with the presence of manure or with the general conditions of cleanliness in production, should, as suggested by Weinzirl, be an excellent test for determining the quality of the raw milk before pasteurization. The results which are shown in Table 5 were on the 10 c. c. and 10-tube basis, because the samples of milk were examined before the value of 20 c. c. quantities of milk was known. When examining the results it should be kept in mind that certified milk shows negative results with this quantity of milk. Consider, now, the results of the sporogenes test with dirty milk shown at the bottom of the table, and what can then be said of the conditions under which the raw milk was produced.

TABLE 5.—*The sporogenes test with milk produced under unknown conditions and milk produced under dirty conditions.*

COMMERCIAL PASTEURIZED MILK.

Sample No.	Sporogenes test in sets of 10 tubes, with 10 c. c. of milk.										Positive tests.	Bacterial count.
1	+	−	−	−	−	−	−	−	−	−	1	3,100
2	+	+	+	+	−	−	−	−	−	−	4	3,500
3	+	+	+	+	−	−	−	−	−	−	4	4,800
4	+	+	+	+	+	+	+	+	−	−	8	5,700
5	+	+	+	+	−	−	−	−	−	−	4	10,400
6	+	+	+	−	−	−	−	−	−	−	3	10,800
7	+	+	+	+	+	+	+	+	+	+	10	12,400
8	+	+	+	+	+	+	+	+	+	−	9	12,500
9	+	+	+	−	−	−	−	−	−	−	3	13,700
10	+	+	+	+	+	+	+	+	−	−	8	15,600
11	+	+	+	+	+	+	+	+	+	+	10	15,800
12	+	+	+	+	+	+	+	−	−	−	7	17,600
13	+	+	+	+	+	+	+	+	+	−	9	17,800
14	+	+	+	+	+	+	+	+	−	−	8	17,800
15	+	+	+	+	+	+	+	+	+	−	9	18,800
16	+	−	−	−	−	−	−	−	−	−	1	19,200
17	+	+	−	−	−	−	−	−	−	−	2	19,300
18	+	+	−	−	−	−	−	−	−	−	2	20,200
19	+	+	+	+	−	−	−	−	−	−	4	20,300
20	−	−	−	−	−	−	−	−	−	−	0	22,800
21	+	+	+	+	+	+	−	−	−	−	6	24,700
22	+	+	+	+	+	+	+	+	+	−	9	25,200
23	+	+	+	+	+	+	+	−	−	−	7	26,900
24	+	+	+	+	−	−	−	−	−	−	4	30,600
25	+	+	−	−	−	−	−	−	−	−	2	41,900
26	+	−	−	−	−	−	−	−	−	−	1	57,000
27	+	+	+	+	−	−	−	−	−	−	4	80,000
28	+	+	+	+	+	−	−	−	−	−	5	345,000

MILK PRODUCED UNDER DIRTY CONDITIONS; COWS DIRTY; UTENSILS NOT STERILIZED.

1	+	+	+	+	+	+	+	−	−	−	7	33,000
2	+	+	+	−	−	−	−	−	−	−	3	46,000
3	+	+	+	+	+	+	−	−	−	−	6	101,000
4	+	+	−	−	−	−	−	−	−	−	2	106,000
5	+	+	+	+	+	+	−	−	−	−	6	107,000
6	+	+	+	−	−	−	−	−	−	−	3	112,000
7	+	+	+	+	+	+	+	−	−	−	7	118,000
8	+	−	−	−	−	−	−	−	−	−	1	129,000
9	+	+	−	−	−	−	−	−	−	−	2	245,000
10	+	+	+	+	+	+	+	+	+	−	9	320,000
11	+	+	+	+	+	+	−	−	−	−	6	750,000
12	+	+	−	−	−	−	−	−	−	−	2	1,340,000
13	+	+	+	+	+	+	+	−	−	−	7	1,810,000
14	+	+	+	+	+	+	+	−	−	−	7	2,900,000
15	+	+	+	−	−	−	−	−	−	−	3	11,600,000
16	+	+	+	+	+	+	−	−	−	−	6	22,500,000
17	+	+	+	+	+	+	+	+	+	+	10	25,000,000
18	+	+	+	+	+	+	−	−	−	−	6	61,000,000

If the sporogenes test is any criterion, it seems evident that the pasteurized milk for the most part was not produced under very clean conditions. It would appear that in general the conditions of production were probably similar to those under which the samples represented at the bottom of the table were produced.

While information as to the production, indicated by the sporogenes test, could not be relied upon to do more than suggest probable conditions, the test might profitably be applied occasionally to milk from individual farms in connection with control work.

THE SOURCE OF THE MAJORITY OF SPORES OF B. ENTERITIDIS SPOROGENES FOUND IN MILK.

It is known that the spores of *B. enteritidis sporogenes* are widely distributed in nature. As stated, they are found in cow manure, cattle feed, soil, and water. In fact, they are so generally distributed that their presence in milk may be interpreted theoretically as contamination from a number of sources. Perhaps they come from various sources, but since they are present in manure in larger numbers than in other material likely to serve as a source of contamination, it seems logical to assume that most of them come from that source.

Race (10) believes, however, that in practice milk cans form a most fruitful source of these organisms. He offers no figures to support his belief, which, if true, naturally would decrease the value of the test as a means of detecting manurial contamination. While contamination by dirty utensils is extremely important from the standpoint of number of bacteria introduced, it is not usually of so serious a nature as that of cow manure. In the consideration of the sporogenes test the influence of utensils, however, can not be overlooked, and a number of samples were run to determine the importance of this factor.

The sporogenes test, using 10 tubes with 20 c. c. of milk, was run on samples of milk produced under dirty conditions with unsterilized utensils. A similar number of tests were then made on milk produced under the same conditions, but with sterilized utensils. Then a third set of tests was made on milk produced from cows which had been cleaned and which were kept clean, but for which the utensils were not sterilized. In fact, the utensils were simply washed with cold water. Small-top pails were used when the cows were clean, in order to exclude as much manure as possible.

From the results of this work, which are shown in Table 6, it will be seen that, taking the samples as a whole, there was very little difference in the sporogenes test between samples produced under dirty conditions with the utensils not sterilized and those produced under dirty conditions with sterilized utensils. It would seem from these results that unsterilized utensils do not contribute to any marked extent to the contamination of milk by spores of *B. enteritidis sporogenes.*

TABLE 6.—*Relation of the sporogenes test to milk produced under varying conditions.*

MILK PRODUCED IN DIRTY BARN; COWS DIRTY; UTENSILS NOT STERILIZED.

Sample No.	Sporogenes test in sets of 10 tubes, with 20 c. c. of milk.										Positive tests.	Bacterial count.
1	+	+	+	+	+	+	+	+	+	−	9	33,000
2	+	+	+	+	+	+	+	−	−	−	7	46,000
3	+	+	+	+	+	+	−	−	−	−	6	101,000
4	+	+	−	−	−	−	−	−	−	−	2	106,000
5	+	+	+	+	+	+	+	+	+	−	9	107,000
6	+	+	+	+	+	−	−	−	−	−	5	112,000
7	+	+	+	+	+	+	+	+	+	−	9	118,000
8	+	+	+	−	−	−	−	−	−	−	3	129,000
9	+	+	+	+	−	−	−	−	−	−	4	245,000
10	+	+	+	+	+	+	+	+	+	+	10	320,000
11	+	+	+	+	−	−	−	−	−	−	4	750,000
12	+	+	+	−	−	−	−	−	−	−	3	1,340,000
13	+	+	+	+	+	+	+	+	+	+	10	1,810,000
14	+	+	+	+	+	+	+	−	−	−	7	2,900,000
15	+	+	+	+	+	+	−	−	−	−	6	11,600,000
16	+	+	+	+	+	+	+	−	−	−	7	22,500,000
17	+	+	+	+	+	+	+	+	+	+	10	25,000,000
18	+	+	+	+	+	+	−	−	−	−	6	61,000,000

SAME AS ABOVE, EXCEPT UTENSILS STERILIZED.

1	+	+	+	+	+	+	+	+	+	+	10	19,000
2	+	+	+	+	+	+	+	−	−	−	7	26,000
3	+	+	+	+	+	+	+	+	+	−	9	32,000
4	+	+	+	−	−	−	−	−	−	−	3	37,000
5	+	+	+	+	+	+	+	+	−	−	8	41,000
6	+	+	−	−	−	−	−	−	−	−	2	56,000
7	−	−	−	−	−	−	−	−	−	−	0	64,000
8	+	+	+	+	+	+	+	+	+	+	10	68,000
9	+	+	+	+	−	−	−	−	−	−	4	76,000
10	+	+	+	+	+	+	+	+	+	+	10	102,000
11	+	+	+	+	+	+	−	−	−	−	6	146,000
12	+	+	+	+	−	−	−	−	−	−	4	163,000
13	+	+	+	−	−	−	−	−	−	−	3	168,000
14	+	+	+	+	−	−	−	−	−	−	4	182,000
15	+	+	+	+	+	+	+	+	−	−	8	186,000
16	+	−	−	−	−	−	−	−	−	−	1	242,000
17	+	+	+	+	+	+	+	−	−	−	7	245,000
18	+	+	+	+	+	+	+	+	−	−	8	560,000

BARN FLOOR CLEAN; COWS CLEAN; UTENSILS NOT STERILIZED.

1	+	−	−	−	−	−	−	−	−	−	1	1,310,000
2	+	+	+	−	−	−	−	−	−	−	3	1,170,000
3	−	−	−	−	−	−	−	−	−	−	0	4,200,000
4	−	−	−	−	−	−	−	−	−	−	0	4,300,000
5	+	−	−	−	−	−	−	−	−	−	1	4,400,000
6	+	+	+	+	+	+	+	+	−	−	8	4,500,000
7	−	−	−	−	−	−	−	−	−	−	0	4,800,000
8	+	−	−	−	−	−	−	−	−	−	1	7,600,000
9	+	−	−	−	−	−	−	−	−	−	1	8,400,000
10	+	−	−	−	−	−	−	−	−	−	1	9,200,000
11	+	+	+	+	−	−	−	−	−	−	4	13,600,000
12	+	+	+	+	+	−	−	−	−	−	5	18,900,000
13	+	−	−	−	−	−	−	−	−	−	1	23,900,000
14	+	+	−	−	−	−	−	−	−	−	2	32,800,000
15	+	−	−	−	−	−	−	−	−	−	1	38,000,000
16	−	−	−	−	−	−	−	−	−	−	0	64,000,000

The results of the sporogenes test with milk produced from clean cows but with dirty utensils tend to confirm this opinion. It will be noted that there was a decided drop in the number of positive tubes in the sporogenes test, although occasional samples did show a rather large number.

The quantity of sediment from each pint of milk produced under these conditions is shown in Plates VI, VII, and VIII. A comparison of the disks on Plates VI and VII shows that the milk produced under dirty conditions with unsterilized utensils and that produced under the same conditions with sterilized utensils, contained about the same quantity of cow manure. As stated, these samples showed about the same results with the sporogenes test.

When the cows were clean there was a decided drop in the quantity of manure found in the milk, as will be noted from the sediment disks in Plate VIII. Reference again to Table 6 shows that under these conditions there was a decided drop in the sporogenes test, although the utensils used in the production of this milk were decidedly dirty. The extent of the contamination which came from these dirty utensils is shown by the remarkably high counts with fresh milk in the lower section of Table 6. From these results it seems evident that, generally speaking, most of the spores of *B. enteritidis sporogenes* which are found in milk are introduced through contamination by cow manure, but that occasionally a high sporogenes test may be the result of contamination by this organism from dirty utensils.

Before considering the value of the sporogenes test any further it seems advisable to revert again to the subject of the lack of correlation between the test and the quantity of cow manure in milk. It has been shown that the test, as carried out by Savage and by Weinzirl, bore no definite relation to the sediment which may be assumed is largely cow manure. In Plates VI, VII, and VIII the results of the sporogenes test are placed in the upper right-hand corner of each square containing a sediment disk, and the total count is shown beneath the disk. Particular attention is called to Plate VII. This shows sediment disks from milk produced under dirty conditions but with sterilized utensils. If there is any positive correlation between the test and cow manure it should show with milk produced under these conditions. In making the test 10 tubes were used, each containing 20 c. c. of milk.

It is evident that with these samples and with this method there was again no definite relation between the test and the manurial content of the milk. Sample 1, for example, showed negative sporogenes test and evidently contained, from the appearance of the disk, as much manure as Samples 14, 15, and 16, in which all 10 tubes were positive.

While there seems to be no definite relation between the sporogenes test and the sediment test when individual samples under a given condition of production are compared, there seems to be a general difference in results when a number of samples produced under dirty conditions are compared with those produced under clean con-

ditions. This has been emphasized in the discussion of the test in connection with certified milk and dirty milk, and is again illustrated by the results shown in the last two sections of Table 6.

SUMMARY AND CONCLUSIONS.

1. The Savage test using 10 tubes with 2 c. c. of milk is not sufficiently delicate to be of great value, evidently, because not enough milk is used in each tube.

2. The Weinzirl test does not appear to correlate with the quantity of manure in milk. This seems to be due both to the method of making the test and to the variation in spore content of *B. enteritidis sporogenes* in manure.

3. The experiments indicate that the majority of spores of *B. enteritidis sporogenes* gain entrance to milk by means of cow manure.

4. With 10 tubes and 20 c. c. of milk to each tube, the sporogenes test as used throughout the experiments shows a fairly definite relation to conditions of production. This relation is more definite than that shown by either the Savage or the Weinzirl test.

None of the tests, however, show a definite correlation between the number of tubes positive and the quantity of manure in any given sample. But with 20 c. c. quantities of milk and discounting individual variation, there is a general trend of agreement between the test and manure.

5. As a rule, the sporogenes test with 10 tubes and 20 c. c. of milk shows high results, that is, a large number of positive tubes with milk produced under dirty conditions. With milk produced under clean conditions, the test is apt to be negative or show only a few positive reactions.

The test tends to differentiate between extremes in methods of production, and naturally most milk will fall between these limits. The nearer the conditions of production approach one extreme or the other, the more accurately will the sporogenes test indicate the conditions.

It must be pointed out, however, that no reliance can be placed on one test with one sample. Individual variation with a single test makes a series of tests on a number of samples necessary for the result to have any significance.

6. When the limitations of the test are understood and the results properly interpreted, its use with a series of samples from a given source should give considerable information as to cleanliness of production, particularly in connection with the extent of manurial pollution. The test, if used, however, should be taken as merely an indication of the conditions of production, and should be verified by an actual inspection at the farm.

LITERATURE CITED.

(1) BARTHEL, CHR.
1910. Obligat anaërobe Bakterien in Milch und Molkereiprodukten. *In* Centbl. f. Bakt. [etc.], 2 Abt., v. 26, no. 1/3, p. 1–47.

(2) BROWN, HERBERT R.
1909. A study of some of the spore-bearing anaërobic bacteria in market milk. *In* 41st Ann. Rpt. Mass. State Bd. of Health, p. 632–667.

(3) CHURCHMAN, JOHN W.
1912. The selective bactericidal action of gentian violet. *In* Jour. Expt. Med., v. 16, no. 2, p. 221–247.

(4) FLÜGGE, C.
1894. Die Aufgaben und Leistungen der Milchsterilisirung gegenüber den Darmkrankheiten der Säuglinge. *In* Ztschr. Hyg. u. Infectionskrank., v. 17, p. 272–342.

(5) FORD, W. W., and PRYOR, J. C.
1914. Observations upon the bacteria found in milk heated to various temperatures. *In* Bul. Johns Hopkins Hosp., v. 25, no. 283, p. 270–276.

(6) HENRY, HERBERT.
1917. An investigation of the cultural reactions of certain anaërobes found in wounds. *In* Jour. Path. and Bact., v. 21, no. 3, p. 344–385.

(7) HOUSTON, A. C.
1905. The bacteriological examination of milk. Report of Medical Officer to the London County Council.

(8) KLEIN, E. E.
1897–1898. Report on the morphology and biology of *Bacillus enteritidis sporogenes*. *In* Rpt. of Med. Officer of Gt. Brit. Local Govt. Bd., appendix B, no. 1, p. 210–250.

(9) PRYOR, J. C.
1914. On the presence of spore-bearing bacteria in Washington market milk. *In* Bul. Johns Hopkins Hosp., v. 25, no. 283, p. 276–278.

(10) RACE, JOSEPH.
1918. The examination of milk for public-health purposes.

(11) RITCHIE, JOHN.
1916. The bacteriological examination of fresh milk. *In* Public Health (London), v. 29, no. 11, p. 270–274.

(12) SAVAGE, WILLIAM G.
1909–1910. Report upon the bacterial measurement of milk pollution. *In* Supp. containing Rpt. of Med. Officer of Gt. Brit. Local Govt. Bd., appendix B, p. 474–503.

(13) SHIPPEN, L. P.
1915. Common organisms in heated milk: their relation to its reactions. *In* Bul. Johns Hopkins Hosp., v. 26, no. 293, p. 257–261.

(14) SIMONDS, J. P.
1915. Studies in *Bacillus welchii*, with special reference to classification and to its relation to diarrhea. Monographs of the Rockefeller Inst. for Med. Research, no. 5.

(15) WEINZIRL, JOHN, and VELDEE, MILTON V.
1915. A bacteriological method for determining manurial pollution of milk. *In* Amer. Jour. Pub. Health, v. 5, no. 9, p. 862–866.

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BULLETIN No. 941

Contribution from the Office of Farm Management and Farm Economics
H. C. TAYLOR, Chief

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FARM MANAGEMENT IN THE OZARK REGION OF MISSOURI.

A STUDY OF THE ORGANIZATION AND OPERATION OF A NUMBER OF REPRESENTATIVE FARMS.

By H. M. Dixon, *Associate Farm Economist*, and J. M. Purdom, *Scientific Assistant*.

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INTRODUCTION.

This bulletin is based on a study of the organization and management of 79 farms distributed in five counties in the southern and southeastern Ozark region of Missouri. Thirty-one of these farms are representative of the conditions of rolling and hilly upland farms: the other 48 are more representative of the conditions on the valley and level-upland farms. Throughout the bulletin these two classes of farms are treated separately.

Data are presented on size of farms, distribution of farm area, capital, receipts and expenses, and the returns in farm income and labor income. The first part of the bulletin treats of the findings largely from the standpoint of the area as a whole, and the latter part is devoted to the consideration of representative individual farms, with a view of emphasizing some of the outstanding factors contributing to success or failure.

SUMMARY.

Topographical structure to a large extent determines the agricultural value of the land. The southern and eastern Ozark region of Missouri is a mountainous plateau, predominantly rough and rocky,

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large areas of which are too rough and stony to admit of cultivation of crops. The areas more adaptable to cultivation have been in farms for many years. As a rule, the operator of a valley or level-upland farm has a decided advantage over the operator of the rough farm.

After deducting from their total receipts the year's operating expenses, including the value of family labor, and allowing 5 per cent interest on the capital invested, the operators of rolling and hilly farms had in 1917 an average labor income of $309, and those operating valley or level-upland farms an average of $646. Of the 79 farms studied, 20 per cent had no labor income after making the above specified deductions from their year's receipts, and 21 per cent had a labor income above $1,000.

FIG. 1.—Map showing region studied.

Labor incomes earned by typical operators indicate that an operator having much less than 40 acres of crop land for a general live-stock farm has a rather poor chance of attaining financial success. The labor income earned by operators increased as the size of the farm increased.

Live-stock farming is the principal agricultural industry of the region.

The production and sale of cream is a growing branch of the live-stock industry. The use of cows for dairy purposes is increasing. The average production per cow of 78 cows on dairy farms was 142 pounds of butter fat. This industry would become more profitable if cows of greater productive capacity were introduced. The production would also be increased by providing a better balanced feed ration.

Live-stock losses are a source of considerable expense in operating a farm. Losses of live stock on the farms for the year studied were as follows: Cattle, 3.6 per cent; horses and mules, 3.4 per cent; sheep, 8.9 per cent; hogs, 10.7 per cent; goats, 11 per cent.

Pasturage is the foundation of the live-stock industry. The natural pastures can be greatly improved by thinning out woodland areas, keeping the underbrush down, and sowing tame grasses.

For greater assurance of live-stock feeds during the summer droughts, to which this section is liable, many farmers plant sorghum, millet, and kafir corn as auxiliary hay crops. On the better

managed farms silage is also produced for winter feed, and the operators are beginning to use it to supplement the pastures during the summer droughts.

With proper care, alfalfa, clover, soy beans, and cowpeas are grown. The possibilities of these crops both for hay and for grazing are becoming more clearly recognized.

The rotation in most frequent use in this region consists of (1) corn, one or two years, (2) winter wheat or spring oats in which grass is seeded, (3) a hay crop cut for one or two years, and pastured from one to three years.

There are many opportunities to obtain land in the Ozarks. A better understanding by prospective purchasers of the possibilities and limitations of this area should bring greater satisfaction in choosing a farm with a given amount of capital to invest.

FIG. 2.—Typical Ozark country.

LOCATION AND CHARACTER OF THE AREA.

The Ozark Plateau of Missouri covers the greater part of the State south of the Missouri River. This region is described by the United States Bureau of Soils as an elevated limestone region. (See fig. 2.) The counties represented in this study were Texas, Howell, Oregon, Reynolds, and Taney, in the southern and southeastern parts of the region. In main topographical features and soils they are similar to all of the eastern part.[1]

[1] The U. S. Bureau of Soils, in cooperation with the University of Missouri, made a general survey of the Ozark region of Missouri and Arkansas, results of which are found in the U. S. Department of Agriculture publication, "Soil Reconnoissance of the Ozark Region of Missouri and Arkansas." Separate soil surveys have been made in a number of counties in this region or are now under way. For a detailed description of the soils in any location reference should be made to the proper soil survey report.

As a general statement, it may be said that while the soils of the area are in the main similar, the amount of soil suitable for cultivation varies greatly in the various counties, and in different locations in the same county, because of differences in topography. The changes from one phase of topography and soil to another occur without regularity and with great abruptness. The soils are locally known as "highland" or "upland" soils, and "lowland" or "valley" soils. The highland soils predominate. The lowlands comprise the bottoms and valleys, and their area is very limited. Intermediate between these two primary groupings is a class of land neither highland nor lowland which is known as "bench" land. (See fig. 3.)

FIG. 3.—Types of Ozark land. In the upper view one looks down from the surrounding hills on a typical river bottom. The lower picture is of a field on what are locally described as "bench" lands.

LOWLANDS.

The "valley" or "bottom" soils of the lowlands vary in character. The best grade of bottom soil occurs in narrow strips along the rivers and creeks. These strips are level and are the best and most fertile farming lands of the region. Their extent, in comparison with the total land area, is very small. The soils locally classed as "valley" lands are, as the name implies, valleys of varying depth, width, and extent, which may be found scattered throughout the entire region. Practically all of the lowlands suitable for cultivation have been in

farms for many years. Of the lowlands the choicest are the bottoms. From this the quality grades down, until in many instances what is described and known locally as valley land is no more desirable than the highlands with a topography sufficiently level to admit of cultivation.

The bench lands, when they occur, are generally in the vicinity of the streams. They lie at a higher altitude than the bottom lands, but are lower than the typical highlands and are usually comparatively

FIG. 4.—Typical phases of Ozark "uplands." The upper view shows the general character of land described in the text as "rolling upland." The lower view is of the more rugged, mountainous country.

level. The area of these lands is small and in point of desirability they class with the valley lands.

HIGHLANDS.

The highlands comprise the great bulk of the land in the Ozark region. A large part of this land, and in some sections the great majority of it, is too rough and stony for cultivation. The topography varies from level to rolling and very steep. (See fig. 4.) In almost

every county level stretches of uplands may be found. These level tracts are the most highly prized of the uplands and from an agricultural standpoint compare favorably with the valleys. (See fig. 5.) Wherever these more level upland tracts are large enough for the establishment of several farms, prosperous communities have been built up, often many miles from a railroad. Very little of the level upland remains uncleared, and the few timbered tracts which are left are scattered and of small area.

In the hilly or rolling uplands of the counties studied farms are found here and there in such places as the original settlers thought could be cleared and farmed to the best advantage. In many places the farms are widely scattered, but in other sections, where the clearing process has been more intensive, farms may be found relatively close together. The greater part of the remaining woodland is probably too rough for profitable cultivation of crops.

FIG. 5.—Type of "level uplands" in the vicinity of Licking, Texas County. Such lands are practically all under cultivation, and prosperous villages will be found near by, though often they are 20 miles from a railroad.

STONES.

Reference has been made to the stony character of this country as a whole. (See fig. 6.) A very small percentage of the area is practically free of stones, and such stone-free ground is almost without exception found in the bottom and in the level-upland soils. The amount of stone is variable. Large areas may be found of solid rock with only a very thin covering of soil. It is evident that such areas can never be of much agricultural value. Very large areas have broken stone of varying sizes and amounts incorporated with the soil. The quantity of such broken stone may be so great that it appears to cover the ground completely. Cultivating such soil entails very hard labor. Where the quantity of stones is sufficient to interfere seriously with cultivation, some farmers make it a practice to remove them. To clear the soil entirely of stones this work has to be done repeatedly for several years, as each plowing brings more stones to the surface. This is a laborious operation, but one which

FIG. 6.—Much of the Ozark country, as illustrated in the upper picture, is underlain by solid rock. Such land, when the rock comes to the surface, is obviously of small agricultural value. Stones of varying sizes are found on practically all lands in the Ozarks. The lower picture shows part of the stones gathered in clearing a field of obstructions to the plow.

is generally practiced by those farmers who have been most successful in building general farms in the rough sections of the area studied.

FERTILITY OF THE SOILS.

The soils of the region, with the exception of the bottom soils, are principally stony and gravelly silts and stony and gravelly silt and clay loams. They are usually porous, owing to the large content of stone and gravel. As a result, air and water circulate through them freely, and when they are put under cultivation the humus content is quickly lost, unless a system of farming is adopted in which provision is made for the systematic replenishment of the supply. If the humus content is lost the water-holding capacity of these soils is greatly reduced, and as a result crops suffer severely during the summer droughts, to which this section seems peculiarly liable, and profitable crop production is then almost an impossibility.

There is a wide variation in the natural fertility and productivity of the soils throughout the area.

TRANSPORTATION FACILITIES.

The rough, hilly, broken character of the region makes railroad construction expensive and difficult; hence, as may be expected, large areas are sometimes 20 to 30 miles from the nearest railroad point. The same natural features which render railroad construction difficult are equally a hindrance to the construction of public roads. (See fig. 7.) A few main automobile highways traverse the region, but even these roads are very bad in places. Bridges have not been built at all needed places, and, as a consequence, travel in a season of high water is difficult and uncertain. The grades, moreover, are often very steep, and these, as well as the gravelly creek bottoms, make it impossible to haul very heavy loads. For farmers who are situated off these main highways and at a distance from a railroad point, the transportation question is rather difficult, for hauling must be done over stony and badly washed roads, often steep and rough.

Increasing attention is being given the roads in this section, particularly the system of main roads, and it is planned to improve the grading of the roads already established, and to build more through and connecting roads. Some of the towns situated several miles from a railroad point have motor truck freight services in operation.

CLIMATE.

This area is just north of the line indicating the northern limit of profitable cotton production, and within the winter wheat territory. The winters are fairly mild, a number of the residents of these counties having come from regions farther north to escape the rigors of the severer winters. The averages of the mean temperatures

FIG. 7.—Difficulties of transportation. The stream in the upper picture can be forded during dry seasons, but during high water the passage could be effected only with difficulty. The lower picture shows a very rough road, broken by outcropping rocks and stone ledges.

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recorded at Houston, Springfield, and Koshkonong are as follows: Winter, 34.5 degrees; spring, 56.1 degrees; summer, 75.4 degrees; fall, 58.8 degrees; annual, 56.2 degrees. The area is subject to sudden changes in temperature, summer temperatures of 83 degrees, 84 degrees, and 86 degrees, respectively, having been recorded at these stations as early as February, while freezing temperatures have been recorded as late as May. Periods of warm growing weather in the spring which caused the sap to rise in dormant vegetation, followed by freezing weather, have been very disastrous to such fruit crops as peaches, and both fruit buds and trees have frequently been killed.

As recorded at five stations, viz, Houston, Mountain Grove, Birchtree, Springfield, and Koshkonong, the average date of occurrence of the last killing frost in spring is April 12. In the northern part of the area, at Houston, the average date is April 20; in the southern part, at Koshkonong, it is April 5. The average date of occurrence of the first killing frost in fall as recorded at these five stations is October 20. The records kept at these stations show the average of the number of days in the growing season to be 183.

The difference of one degree in latitude between the northern and southern parts of the area results in a difference of 26 days in the average growing season. Thus, in the lower part of the area spring vegetation and grass begin to grow two or three weeks earlier than in the northern part, and, consequently, cattle can be turned on pasture about two weeks earlier. The grazing period in the fall is also longer for the southern area than for the northern; the value of this, however, is not so great as the earlier grazing in the spring.

RAINFALL.

The rainfall at the five stations, Houston, Mountain Grove, Birchtree, Springfield, and Koshkonong, would seem to indicate an abundance of rain, the average in inches being as follows: Winter, 7.97; spring, 12.93; summer, 13.29; fall, 8.88; annual, 43.07. It is seldom, however, that the average rainfall and distribution is recorded in any particular year. The spring and summer rainfall is the most vital, and the distribution of the rainfall is a factor equal in importance to the amount.

The year 1917 was commonly reported as a year favorable to crop production, but all farmers interviewed were unanimous in reporting that for a number of years prior to 1917 this region was visited by disastrous droughts with great resulting damage to crops, especially corn, and to pasture. Precipitation records bear out this statement. The records kept at the five stations above mentioned show their average rainfall for 1917 to have been 41.7 inches, or within 2 inches of the average annual rainfall for the region. The distribution was

also equally favorable, the average precipitation in inches recorded at these five stations for the five vital spring and summer months being as follows: April, 7.41; May, 3.68; June, 4.74; July, 4.41; and August, 5.75.

The monthly precipitation records at Springfield for 40 years, 1877–1916, inclusive (records for the year 1881 not available), show that 17 of the 40 were years which may be called drought years; that is, years in which a rainfall of less than 2 inches fell in one or more of the five months, April to August, inclusive, and that 11 times in the 40 years two consecutive months, of the five-month period, April to August, passed with a total rainfall of less than 5 inches. (See fig. 8.)

FIG. 8.—An artificial pond in the Ozark uplands. Getting water for live stock is frequently a serious problem in sections of the Ozarks, and artificial ponds or reservoirs are often resorted to for furnishing a supply. In periods of severe drought these frequently go dry. It then becomes necessary to drive the stock long distances to a spring creek or to sink a deep well.

Dividing this period into four 10-year periods, the frequency of occurrence of these years of drought in each period follows:

Frequency of occurrence of years of drought.

Item.	1877–1886	1887–1896	1897–1906	1907–1916	1877–1916
Number of years in which less than 2 inches of rain fell in one or more of the months April to August, inclusive	2	5	3	7	17
Number of years in which less than 5 inches of rain fell in 2 consecutive months during the months April to August, inclusive	2	2	3	4	11

It is seen that during the four periods of 10 years each for which weather records are available the years in which there was a marked deficiency of rainfall were much fewer in each of the three preceding 10-year periods than in the last 10-year period. We may therefore infer that in any period of 10 years at least two and probably more years may be expected in which drought conditions will obtain more or less, and crop production suffer accordingly.

FARM BUSINESS AND INCOME.

The farms surveyed were classed in one of two divisions, based upon considerations of soil and topography. The first of the divisions comprises the farms located on rolling uplands, hills, and ridges, and these will be referred to in the following text as "rolling and hilly" farms. The second includes those located on the creek bottoms, valleys, bench lands, and level uplands, and these will be referred to as "valley and level-upland" farms. The farms in the first division are operated under difficulties of varying proportions due to topography and the presence of stones; the farms in the second division are in the main fairly level and free from stone. Practically every farm studied in this region included an acreage of rough woodland, and in most instances the greater part of this woodland can never be utilized economically for cultivation.

In Table I is shown by classes the size of farm, acres of crops, capital, receipts, expenses, and income for rolling and hilly farms and valley and level-upland farms, for the year 1917. The table furnishes a measure of the relative importance of the size of farm, capital, receipts, and expenses for the farms when grouped according to the number of acres devoted to crops. The rolling and hilly upland farms were placed in two groups, those with 40 acres or under in crops and those with over 40 acres in crops. The average size of the farms in the smaller-size group was 128 acres, with 26 acres in crops and $3,832 capital, while the larger-size group averaged 240 acres per farm with 72 acres of crops and $7,133 capital.

The valley and level upland farms showed a wide range in size, and were placed in three groups, namely, those with 40 acres or under in crops, those with from 40 to 70 acres, and those with over 70 acres. The farms with 40 acres or under in crops averaged 29 acres in crops and had an investment of $4,631 per farm. Those with from 40 to 70 acres in crops averaged 52 acres in crops and an investment of $8,937. Those with 70 acres or more in crops averaged 105 acres in crops and an investment of $12,602.

FARM INCOME AND LABOR INCOME.

The farm income represents the difference between the gross income and the expenses. As the farmer's time is not included in the expenses of the farm, his earnings are included in the income figure. The earnings of the capital invested in the farm business are also included in this figure. To separate the two and arrive at the earnings of the farmer due to his work and supervision, interest at the rate of 5 per cent on the capital invested has been allowed as the earnings due to the capital in the business, and the remainder of the farm income is considered to represent the farmer's cash earnings for

his year's work, called the farmer's labor income. In addition to the labor income the farmer has the use of a house, and the food and fuel furnished the family by the farm. The farmer's labor income, to a certain degree, measures the relative efficiency with which the farm is managed.

The family income represents the amount that is left from the total farm receipts for the use of the family after deducting the year's farm expenses excluding value of family labor, and including interest paid on indebtedness. The family income on the rolling and hilly farms averages $759, and on the valley and level-upland farms $1,331. This represents the amount available to these families, on the average, for living expenses and savings.

The labor income as reported does not include the value of farm products used for home consumption. While the values of farm-furnished supplies toward the family living were not ascertained upon these farms, it was evident that these represented a considerable item. Wheat and corn raised on the farm furnished practically all of the bread and cereals. Hogs butchered for home consumption furnished a large portion of the meat consumed. A large amount of poultry and eggs and dairy products was likewise used, and practically every farm provided potatoes, garden vegetables, and some fruit and sirup for the home.

A study of 950 farms in 14 areas for the years 1913 and 1914,[1] showed an average value of food, fuel, and house rent furnished the farm family by the farm of $423 per farm, or $90 per person. Of this amount, $260, or $55 per person, was for food, $31, or $7 per person, was for fuel, and $132, or $28 per person, was for house rent. Thus a farmer with a relatively small labor income can maintain a plane of living comparable with that of the city man who earns a considerably larger salary.

The average labor income and farm income for valley farms are considerably higher than for the hill farms, as might be expected. For the small-farm group of the hilly farms shown in Table I the average farm income was found to be $357, and for the larger-farm group $819, with an average for all of $580; the average labor income was $165, $462, and $309, respectively. Similarly, for the valley farms shown in this table, the average farm income was $436, $1,038, and $1,707 for the three size-groups, and the average labor income $204, $591, and $1,077, respectively. Every condition for the year which the records cover was favorable to a good labor income for the operators. The seasons had been good, with good crops and pasture and a good acorn and mast crop. The price of every article sold from the farm was higher than in previous years. Farm expenses

[1] U. S. Department of Agriculture Bulletin 410, "Value to Farm Families of Food, Fuel, and Use of House."

were higher also, but farmers expressed the feeling that increase in income more than compensated for the increased expenses. Even at this, however, the income of the majority of these farmers was none too large to meet a satisfactory standard of living.

The operation of a general farm with much less than 40 acres of land for crops is exceedingly unsatisfactory, regardless of the location of the farm, whether among the valleys or among the hills. Size of business is an important factor in farming throughout this area, but it is also true that the limit to the number of acres of crops which can be profitably included in one farm by the average operator is reached more quickly with farms of rough and stony character than in the case of farms with land more easily cultivated, and perhaps this limit has been reached by some of the larger hill farms.

The hand work involved in making a profit in farming on the poorer of the lands in this region is not generally recognized. Much of the land throughout the area changes hands often, and many of those who purchase such farms, especially those who try to operate small farms with limited capital, must face a most difficult economic problem.

TABLE I.—*Summary of the farm business on 31 rolling and hilly farms and 48 valley and level-upland farms, Ozark region, Missouri, 1917.*

Item.	Rolling and hilly farms.			Valley and level-upland farms.			
	Under 40 crop acres (16 farms).	40 crop acres and over (15 farms).	All farms (31).	Under 40 crop acres (12 farms).	40 to 70 crop acres (21 farms).	70 crop acres and over (15 farms).	All farms (48).
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Farm area	128.3	239.7	182.1	113.8	206.0	329.8	221.7
Crop area	26.4	71.8	48.3	29.1	52.4	105.2	63.1
Improved pasture area	19.4	33.9	26.4	23.6	48.6	76.6	51.1
Woods fenced	40.4	68.7	54.1	23.7	24.1	97.9	47.1
Waste and woodland area	41.3	64.4	52.5	33.2	76.7	46.9	56.5
Rented out area	.8	.9	.8	4.2	4.2	3.2	3.9
Capital	$3,832	$7,133	$5,430	$4,631	$8,937	$12,602	$9,006
Receipts	617	1,618	1,101	850	1,708	2,887	1,861
Expenses	260	799	521	414	670	1,180	765
Farm income	357	819	580	436	1,038	1,707	1,096
Interest on investment at 5 per cent	192	357	271	232	447	630	450
Labor income	165	462	309	204	591	1,077	646
Operator's labor	358	521	435	373	455	483	444
Farm income	357	819	580	436	1,038	1,707	1,096
Value of unpaid family labor	82	351	212	205	248	377	278
Interest on indebtedness	37	29	33	27	33	69	43
Family income	402	1,141	759	614	1,253	2,015	1,331
Per cent return on capital	0.03	4.2	2.7	1.4	6.5	9.7	7.2

The Ozarks offer certain limited opportunities of acquiring land upon which profitable farming may be carried on. Conditions, however, are so varied, and, usually, so unlike those to which the average newcomer to the Ozarks is accustomed, that no stranger should attempt to buy a farm without first making a careful examination

of the property himself, and acquainting himself fully with the conditions under which his operations will have to be carried on. If prospective purchasers before selecting a given farm would acquire a more intimate knowledge of these lands and their agricultural possibilities and limitations, they would take an important step toward putting the agriculture in many of these areas upon a more stable and satisfactory basis.

FARM INVESTMENT.

The investment of these farms consists of the value of the land and buildings, of live stock, of machinery used in operating the farm, and of feed and supplies on hand, together with the cash needed for meeting current expenses before farm receipts are sufficient to meet operating expenses. Table II shows the distribution of capital for the various size-groups of hill and valley farms. The investment in land and buildings constitutes the major part of the capital. Next in order of importance come live stock, machinery, cash for operation, and feed supplies.

REAL ESTATE.

The real estate investment—the value of land and improvements—averages $3,701 for the hilly farms and $6,539 for the valley farms. The better buildings are on the valley farms. Real estate averaged in value $20 per acre for the hilly and $30 per acre for the bottom and level upland farms.

The value of the land was estimated on the basis of the entire farm with buildings and improvements. The average per acre of the groups of farms with a small, medium, and large area of crops per farm follows:

Value of real estate.

Class of farm.	Small farms.	Medium-sized farms.	Large farms.	All farms.
Rolling and hilly farms	$23	$20	$18	$20
Valley and level-upland farms	35	32	26	30

LIVE STOCK.

About one-fifth of the capital of these farms is invested in live stock. Almost universally the farmers in this region follow some branch of the live-stock industry. In the case of the larger farms, the investment in live stock at the beginning of the year does not give a correct measure of the proportion of capital used in the live-stock industry, for the reason that in the case of the hill farms the live-stock business is mainly restricted to the stock on hand and the increase, whereas in the case of the large bottom farms a considerable portion of the cash to run farms is used in buying and feeding additional live stock.

MACHINERY.

The machinery investment usually covers equipment for a combination of grain and live-stock farming. For the grain crops, binders and drills are needed, and for the live stock many of the farmers are putting in silos, which necessitates gasoline engines and cutters. These expensive items of equipment are to some degree purchased cooperatively, but frequently a farmer is so far from his nearest neighbor with similar requirements that he is forced to buy them individually.

FEED AND SUPPLIES.

The item of feed and supplies covers feeds and farm supplies on hand at the beginning of the farm year, which for this survey was the spring of 1917. The year 1916 had been unfavorable to the production of crops in this region, and most of the feed raised had been fed during the winter. Few farmers had more feed on hand than was necessary to feed their work stock until the 1917 harvest. Many were depending entirely on pasture, together with small pur-

FIG. 9.—Red clover, as it grows on "level upland." In point of desirability these lands class with the "valley" lands.

chases of grain concentrates, to eke out until the oat crop was ready to feed. The crop year 1917 was favorable, thereby enabling the farmers to carry sufficient feed and supplies for the following spring feeding without the purchase of as much feed as was necessary the previous year.

CASH TO RUN THE FARM.

The average amount of cash reported by the operator as on hand during the year to meet farm expenses increases regularly as the size of farm increases. The large amount reported for the largest-size group of valley and bottom farms is due to the fact that the buying and feeding of stock is practiced by these farmers. In some instances a bunch of feeder cattle or hogs may be bought and carried through

the feeding period; in others, stock cattle and hogs from the range are bought as offered for sale and put in shape for the market.

TABLE II.—*Distribution of capital on 31 rolling and hilly farms, and 48 valley and level-upland farms, Ozark region, Missouri.*

Item.	Rolling and hilly.					
	Under 40 crop acres (16 farms).		40 crop acres and over (15 farms).		All farms (31).	
	Investment.	Per cent.	Investment.	Per cent.	Investment.	Per cent.
Land	$2,152	56.2	$3,459	48.5	$2,784	51.2
Dwelling	522	13.6	634	8.9	576	10.6
Other buildings	214	5.6	476	6.6	341	6.3
Live stock	684	17.8	1,678	23.5	1,165	21.5
Machinery	138	3.6	499	7.0	313	5.8
Feed and supplies	24	.6	97	1.4	60	1.1
Cash	98	2.6	290	4.1	191	3.5
Total capital	3,832	100.0	7,133	100.0	5,430	100.0

Item.	Valley and level upland.							
	Under 40 crop acres (12 farms).		40 to 70 crop acres (21 farms).		70 crop acres and over (15 farms).		All farms (48).	
	Investment.	Per cent.	Investment.	Per cent.	Investment.	Per cent.	Investment.	Per cent.
Land	$2,614	56.5	$5,099	57.1	$6,819	54.1	$5,015	55.7
Dwelling	548	11.8	960	10.7	980	7.8	863	9.6
Other buildings	280	6.0	627	7.0	1,011	8.0	661	7.3
Live stock	814	17.6	1,460	16.3	2,023	16.0	1,475	16.4
Machinery	225	4.8	484	5.4	541	4.3	437	4.8
Feed and supplies	31	.7	77	.9	71	.6	63	.7
Cash	119	2.6	230	2.6	1,157	9.2	492	5.5
Total capital	4,631	100.0	8,937	100.0	12,602	100.0	9,006	100.0

CROPS.

The list of crops in Table III shows the utilization of the crop land. The cropping system which is followed in a general way, by the majority of the farmers in this region, consists of (1) corn for one or two years, (2) wheat or oats, and (3) timothy and clover cut for hay as long as the stand remains good, and then pastured from one to three years. (See fig. 9.) In point of acreage corn occupies first place, followed in the order named by hay, wheat, and oats. About one-third of the crop area is in corn and one-fourth in mixed hay.

TABLE III.—*Distribution of crop area on 31 rolling and hilly farms and 48 valley and level-upland farms, Ozark region, Missouri.*

Crop.	Rolling and hilly farms.					
	Less than 40 crop acres (16 farms).		40 crop acres and over (15 farms).		All farms (31).	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
Corn	10.6	40.2	21.9	30.5	16.1	33.4
Wheat	.8	3.0	9.2	12.8	4.8	10.0
Oats	.7	2.6	3.9	5.4	2.2	4.6
Rye	1.3	4.9	.4	.6	.9	1.9
Mixed hay	4.3	16.3	21.2	29.5	12.5	25.9
Alfalfa, soy-bean and cowpea hay	.7	2.6	4.7	6.6	2.6	5.4
Other hay	2.7	10.2	5.9	8.2	4.2	8.7
Apples and peaches	2.1	8.0	3.6	5.0	2.8	5.8
Other crops	4.0	15.2	4.3	6.0	4.1	8.5
Double cropped	(.8)	(3.0)	(3.3)	(4.6)	(2.0)	(4.2)
Total	26.4	100.0	71.8	100.0	48.2	100.0

Crop.	Valley and level-upland farms.							
	Less than 40 crop acres (12 farms).		40 to 70 crop acres, (21 farms).		70 crop acres and over (15 farms).		All farms (48).	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
Corn	15.2	52.2	16.7	31.9	35.5	33.8	22.2	35.2
Wheat	2.7	9.3	7.2	13.7	20.1	19.1	10.1	16.0
Oats	2.7	9.3	4.1	7.8	9.6	9.1	5.5	8.7
Rye	.5	1.7	1.1	2.1	3.0	2.9	1.5	2.4
Mixed hay	3.8	13.0	15.9	30.4	29.2	27.8	17.0	26.9
Alfalfa, soy-bean and cowpea hay			2.4	4.6	2.2	2.1	1.8	2.9
Other hay	2.2	7.6	3.5	6.7	3.2	3.0	3.1	4.9
Apples and peaches	2.1	7.2	2.1	4.0	3.4	3.2	2.5	3.9
Other crops	1.3	4.5	1.8	3.4	1.2	1.1	1.5	2.4
Double cropped	(1.4)	(4.8)	(2.4)	(4.6)	(2.2)	(2.1)	(2.1)	(3.3)
Total	29.1	100.0	52.4	100.0	105.2	100.0	63.1	100.0

Alfalfa was grown by a few farmers, not in all cases with success. Soy beans were grown by only a few farmers, as a hay crop or in corn for silage. Only a few acres of cowpeas were planted in the area. A few acres of kafir corn, millet, sorghum, or oats for hay were grown by a majority of the farmers as auxiliary hay crops. These crops are designated in the table as "Other hay." On practically every farm an acreage was devoted to apples. These, however, on most of the farms are receiving little attention and the trees are dying out, the orchards being used for the production of other crops or for pasture. Peaches, likewise, have been unsatisfactory and are not being replanted. "Other crops" in the table includes potatoes, sorghum for sirup, sweet potatoes, cotton, field beans, blackberries, strawber-

ries, pears, cherries, milo maize, buckwheat, rape, spelt, Egyptian wheat, and broom corn grown, more or less, in small acreages. Potatoes were found on most of the farms, and so also was sorghum for sirup, practically every farm having a small acreage of these two crops for home use, the amount raised in excess of home requirements being disposed of on local markets. Double cropping is not practiced to any considerable extent.

The yields obtained during the year of the survey were normal for a good season.

PASTURE.

While the free range still furnishes the greater part of the pasture, increasing attention is being given to pasture on the farm. Pasture on the farm consists of crop land pastured according to the rotation outlined above, and fenced woods and other land not suitable for crops on which pasture grasses have been planted or the growth of the native grasses encouraged. The farm area pastured does not furnish a measure of the pasture utilized by the farms, for the reason that practically every operator to a greater or less degree utilized the pasturage on the range in addition to his farm pasturage.

CROP PRODUCTION AND YIELDS.

In Table IV are shown the yields per acre and the production and sales of the more important crops per farm. On the hilly farms a small amount of a number of crops are sold, while on the valley and level-upland farms most of the crop sales are from corn and wheat. The yields are considerably better on the valley farms.

TABLE IV.—*Yield per acre and amount and value of sales of crops reported by operators of farms from which records were obtained.*

Crop.	Rolling and hilly farms (31 farms).				Valley and level-upland farms (48 farms).			
	Yield per acre.	Total production per farm.	Sales per farm.		Yield per acre.	Total production per farm.	Sales per farm.	
			Amount.	Value.			Amount.	Value.
Corn for grain.....bushels..	23	358	22	$23	32	667	65	$89
Wheat.....do....	10	50	16	36	12	123	87	175
Rye.....do....	8	6	2	3	17	24	8	9
Oats.....do....	24	51	8	6	25	128	15	11
Timothy and clover.....tons..	.6	8.3	.2	2	.7	12	1	18
Sorghum sirup.....gallons..	58	32	13	12	94	19	10	7
Miscellaneous.....	.....	.....	.....	46	.....	.....	.....	24
Apples.....	.....	.....	.....	26	.....	.....	.....	.....
Field beans.....bushels..	7	3	3	17	.....	.....	.....	.....
Total.....	.....	.....	.....	171	.....	.....	.....	333

FARM RECEIPTS.

The greater part of the income of this territory, as shown in Table V, is contributed by the live stock. In the upland division, live stock produced 66.3 per cent of the average receipts for all farms. It is seen that, regardless of character of land operated, the region as a whole is dependent upon live stock for the greater part of its income. Over 30 per cent of the income is from cattle and dairy products, 18 per cent from hogs, 16 per cent from crops, and the rest distributed in small proportions among a number of items.

TABLE V.—*Distribution of receipts on 31 rolling and hilly farms and 48 valley and level-upland farms, Ozark region, Missouri.*

Crop.	Rolling and hilly.					
	Under 40 crop acres (16 farms).		40 crop acres and over (15 farms).		All farms (31).	
	Receipts.	Per cent.	Receipts.	Per cent.	Receipts.	Per cent.
Crops	$107	17.3	$240	14.8	$171	15.5
Dairy products	48	7.8	110	6.8	78	7.1
Cattle	154	25.0	390	24.1	268	24.3
Horses and mules	38	6.2	82	5.1	59	5.4
Sheep and goats	13	2.1	84	5.2	47	4.3
Hogs	112	18.1	304	18.8	205	18.6
Poultry	46	7.4	101	6.2	73	6.6
Miscellaneous	54	8.8	41	2.5	48	4.4
Increase feed and supplies	45	7.3	266	16.5	152	13.8
Total	617	100.0	1,618	100.0	1,101	100.0

Crop.	Valley and level.							
	Under 40 crop acres (12 farms).		40 to 70 crop acres (21 farms).		70 crop acres and over (15 farms).		All farms (48).	
	Receipts.	Per cent.	Receipts.	Per cent.	Receipts.	Per cent.	Receipts.	Per cent.
Crops	$149	17.5	$214	12.5	$646	22.4	$333	17.9
Dairy products	45	5.3	246	14.4	74	2.6	142	7.6
Cattle	207	24.4	450	26.3	828	28.7	507	27.3
Horses and mules	55	6.5	92	5.4	120	4.2	91	4.9
Sheep and goats	8	.9	82	4.8	111	3.8	72	3.9
Hogs	136	16.0	226	13.2	623	21.5	328	17.6
Poultry	84	9.9	158	9.3	83	2.9	116	6.2
Miscellaneous	48	5.6	36	2.1	26	.9	36	1.9
Increase feed and supplies	118	13.9	204	12.0	376	13.0	236	12.7
Total	850	100.0	1,708	100.0	2,887	100.0	1,861	100.0

FARM EXPENSES.

Table VI gives the distribution of expenses on the various size-groups of farms. The largest expense item is that for labor, which is performed mostly by members of the operator's family. The value of the operator's own labor is not charged in the farm expenses. The farms are operated on as close and economical a basis as it seems possible to do. This, indeed, in the majority of cases is an absolute

necessity. Expenses included in "other expense" in the table are such as feed grinding, horse-shoeing, breeding fees, veterinary fees, stock medicine, twine, thrashing, other machine work hired, and similar small miscellaneous items.

TABLE VI.—*Distribution of expenses on 31 rolling and hilly farms and 48 valley and level-upland farms, Ozark region, Missouri.*

Crop.	Rolling and hilly farms.					
	Under 40 crop acres (16 farms).		40 crop acres and over (15 farms).		All farms (31).	
	Expenses.	Per cent.	Expenses.	Per cent.	Expenses.	Per cent.
Hired labor	$6	2.3	$83	10.4	$43	8.2
Family labor	82	31.5	351	43.9	212	40.7
Repairs, machinery	9	3.5	26	3.3	17	3.3
Repairs, buildings and fences	16	6.2	43	5.4	29	5.6
Feed bought	50	19.2	64	8.0	57	10.9
Seed bought	15	5.8	40	5.0	27	5.2
Fertilizer bought	1	.4	18	2.3	9	1.7
Other expenses	45	17.3	93	11.6	69	13.3
Depreciation on machinery and buildings	36	13.8	81	10.1	58	11.1
Total	260	100.0	799	100.0	521	100.0

Crop.	Valley and level.							
	Under 40 crop acres (12 farms).		40 to 70 crop acres (21 farms).		70 crop acres and over (15 farms).		All farms (48).	
	Expenses.	Per cent.	Expenses.	Per cent.	Expenses.	Per cent.	Expenses.	Per cent.
Hired labor	$22	5.3	$61	9.1	$286	24.2	$121	15.8
Family labor	205	49.5	248	37.0	377	32.0	278	36.3
Repairs, machinery	12	2.9	21	3.1	35	3.0	23	3.0
Repairs, buildings and fences	25	6.0	36	5.4	69	5.9	44	5.8
Feed bought	29	7.0	79	11.8	56	4.7	59	7.7
Seed bought	11	2.7	31	4.6	43	3.6	30	3.9
Fertilizer bought	9	2.2	12	1.8	19	1.6	13	1.7
Other expenses	56	13.5	96	14.3	190	16.1	115	15.1
Depreciation on machinery and buildings	45	10.9	86	12.9	105	8.9	82	10.7
Total	414	100.0	670	100.0	1,180	100.0	765	100.0

During the year covered by the records it was not necessary for the Ozark farmers to buy a great amount of feed, that purchased consisting mainly of concentrates for winter feeding and feed bought in the early spring to carry stock until the harvest. However, in drought years the purchase of feed becomes a necessary and heavy expense, the only alternative being to sell the stock, and many farmers who live long distances from a shipping point have sometimes found it necessary to do this.

CROP MANAGEMENT.

More records were obtained of farms having a small number of acres cropped than of farms having a large number. Among the upland farms in this region there seem to be many more small than large farms, largely because of the topography and the limited financial means of many of the operators. The labor incomes earned indicate that the operators of the large farms have an increasing advantage over the operators of small farms. In Table VII is shown the acreage on the various farms devoted to growing different crops. On all the farms, of course, the topography and the stone content of the soil, as well as the scarcity of labor, influence the number of acres that can be devoted to crops. From this table it is seen that the farms having under 40 acres of crops had considerably smaller acreage devoted to each of the various crops than did the farms having a larger area of land cropped.

TABLE VII.—*Number of farms reporting major crops, by acreages grown.*

ROLLING AND HILLY FARMS.

Number of acres reported.	Farms having under 40 acres of cropped land.					Farms having over 40 acres of cropped land.					All farms reporting.				
	Corn.	Wheat.	Oats.	Meadow hay.	Kafir, millet, and sorghum hay.	Corn.	Wheat.	Oats.	Meadow hay.	Kafir, millet, and sorghum hay.	Corn.	Wheat.	Oats.	Meadow hay.	Kafir, millet, and sorghum hay.
None	2	14	11	8	7	....	4	5	3	4	2	18	16	11	11
1–5	2	1	5	3	6	....	....	6	....	6	2	1	11	3	12
6–10	3	1	....	1	3	....	4	4	1	2	3	5	4	2	5
11–15	5	....	....	3	.....	3	4	....	4	2	8	4	....	7	2
16–20	4	....	....	1	.....	5	3	....	1	.....	9	3	....	2	.....
21–25	....	....	....	....	.....	6	....	....	2	1	6	....	....	2	1
26–30	....	....	....	....	.....	1	....	....	....	.....	1	....	....	....	.....
31–35	....	....	....	....	.....	1	....	....	....	.....	1	....	....	....	.....
36–40	....	....	....	....	.....	....	....	....	....	.....	....	....	....	....	.....
41–45	....	....	....	....	.....	....	....	....	....	.....	....	....	....	....	.....
46–50	....	....	....	....	.....	....	....	....	3	.....	....	....	....	3	.....
Over 50	....	....	....	....	.....	....	....	....	1	.....	....	....	....	1	.....

VALLEY AND LEVEL-UPLAND FARMS.

Number of acres reported.	Corn.	Wheat.	Oats.	Meadow hay.	Kafir, millet, and sorghum hay.	Corn.	Wheat.	Oats.	Meadow hay.	Kafir, millet, and sorghum hay.	Corn.	Wheat.	Oats.	Meadow hay.	Kafir, millet, and sorghum hay.
None	....	9	6	6	8	1	12	12	6	22	1	21	18	12	30
1–5	1	2	3	2	1	1	1	11	1	4	2	3	14	3	5
6–10	3	1	3	3	3	3	5	5	4	6	6	6	8	7	9
11–15	2	....	....	1	.....	11	5	4	5	3	13	5	4	6	3
16–20	4	....	....	....	.....	6	4	2	3	1	10	4	2	3	1
21–25	2	....	....	....	.....	2	5	1	3	.....	4	5	1	3	.....
26–30	....	....	....	....	.....	3	2	1	7	.....	3	2	1	7	.....
31–25	....	....	....	....	.....	3	....	....	2	.....	3	....	....	2	.....
36–40	....	....	....	....	.....	2	1	....	1	.....	2	1	....	1	.....
41–45	....	....	....	....	.....	....	....	....	1	.....	....	....	....	1	.....
46–50	....	....	....	....	.....	2	1	....	1	.....	2	1	....	1	.....
Over 50	....	....	....	....	.....	2	....	....	2	.....	2	....	....	2	.....

Oats, kafir, millet, and sorghum crops are utilized as auxiliary sources of feed, and the feed requirements of the farms determine the acreage devoted to these crops. These crops were grown more frequently on the hilly farms.

CORN.

Corn is relied upon as the main feed crop of the region, and on practically every farm as many acres of it are put in as possible. A rotation system has been definitely adopted on farms in many sections. In other sections the system has not been so definitely worked out, and on some of the most fertile bottom farms corn is planted year after year. The thin soils of this region will not stand continuous corn cropping, and the general practice is to plant corn one or two years, followed in the fall by wheat or in the spring by oats. With the winter cereal, grass and clover are seeded, and during the following years hay is cut as long as the stand remains good. After haying, the sod may be devoted to pasture for a few years.

The two most important problems with which these farmers are faced in crop production are frequency of droughts, to which this country is subjected, and the low productivity of the soils.

The Missouri State Board of Agriculture has for a number of years published estimated yields of crops by counties, and to show how seriously the corn crop is affected by droughts in this region the following table is presented, giving such yields for the county of Texas, together with the precipitation for July and August recorded at Houston, Texas County.

TABLE VIII.—*Yield of corn and rainfall.*

Year.	Total yield of corn in Texas County.	Combined July and August rainfall at Houston.	Year.	Total yield of corn in Texas County.	Combined July and August rainfall at Houston.
	Bushels.	*Inches.*		*Bushels.*	*Inches.*
1907	830,963	3.72	1913	671,749	4.68
1908	964,100	6.13	1914	313,140	7.03
1909	1,027,120	9.02	1915	680,600	11.10
1910	1,551,056	10.51	1916	843,291	3.54
1911	1,087,860	11.40	1917	1,019,568	6.62
1912	1,085,133	10.86			

The frequency of rainfall throughout the growing season is a very important factor. To illustrate, the July-August total precipitation was almost identical in 1917 and 1914, but in 1914 6.07 inches of rain fell in August, while in May, June, and July, respectively, but 0.24, 0.85, and 0.96 inches of rain fell. In 1917 the May, June, July, and August precipitation in inches was 2.25, 3.18, 3.35, and 3.27, respectively. In 1914 the corn crop was 313,140 bushels and in 1917 1,019,568 bushels.

Many factors besides rainfall can have a very great influence upon crop yields. The above table, however, does show in a general way how very seriously the corn crop has been affected by droughts in this county; and farmers, not only in this county but in every county

visited, appreciate the effect of this factor upon their returns over a period of years.

For greater assurance of returns the farmer is interested in a system of farming which will economically maintain humus in the soil, and thus add to its water-holding and drought-resisting capacity.

The sale of corn is relied upon to some extent for income, but more generally corn is raised to meet the live-stock needs. As shown in Table IV, the yield of corn throughout this region is low. Many farmers, however, are increasing their yields by feeding most of their crops to live stock, thereby returning a good supply of manure to the soil each year.

SILAGE.

Five of the operators with upland farms and ten of the operators with bottom and valley farms had silos. The use of silage has long proved to be profitable under certain conditions and is being increasingly practiced by farmers in this region. Some farmers harvest the corn and put up the stalks for silage. The use of saccharine sorghums for silage has been tried in only an experimental way by a few of the farmers, but with favorable results. Sorghum makes satisfactory silage, and in view of its excellent drought-resisting qualities it should have an important place among the farm crops of this region. In certain sections of the South it is used for this purpose almost to the exclusion of corn, and uniformly good results are obtained. Pastures suffer along with other crops during the periods of drought, and many farmers in this area, particularly those extensively engaged in dairying, realize more and more the importance of providing silage for the winter feeding period, and to supplement the pastures during the periods of drought.

WHEAT.

The greater part of the crop receipts was from the sale of wheat. The soils throughout this area can not stand continuous grain farming. Wheat and other grains should remain, as they are now, subsidiary crops on the general live-stock farm. Winterkilling does not occur to any great extent. During the year of the survey, however, 45 acres of wheat, or 7 per cent of the acreage planted, was so killed on the farms from which records were obtained.

RYE AND BARLEY.

Rye and barley are relatively unimportant crops in this region, though on the thinner soils in the "uplands" rye would perhaps bring as good returns as wheat. Rye was grown more often than barley.

TIMOTHY AND CLOVER.

Timothy and clover are the main hay crops at present, and both do well in good seasons. The humus content of the soil is very low on some farms, and where such is the case it is difficult to get a good growth of clover. However, clover does well where the soils are kept in good condition by a proper system of crop rotation and pasturing. For greater assurance of a crop of hay most farmers make it a practice to plant both timothy and clover in seeding meadows.

ALFALFA, SOY BEANS, AND COWPEAS.

A very limited area was planted to alfalfa, soy beans, and cowpeas. A few operators were found raising a few acres of alfalfa with moderate success on the better grades of soil. If the known precautions against acidity are taken and the soil inoculated, the area can be profitably increased. In establishing alfalfa liberal application of stable manure has been found necessary on most of the farms. Soy beans were also grown by a few of the farmers from whom records were obtained, usually a limited area in corn for silage, and in two or three instances as a separate hay crop. The acreage of this crop could well be increased, both for the purposes just mentioned and also as a grazing crop for hogs. Cowpeas do well, and make an excellent hay. They could be sown to advantage with the sorghum and millet hay, and the quality of the hay would be greatly improved without materially decreasing the tonnage. Certainly, more leguminous crops should be raised, both because of their soil-building powers and also to afford additional feed for stock. The price of concentrates, cotton-seed meal, bran, linseed meal, etc., is extremely high, and many of the operators have abandoned feeding them. Unless satisfactory substitutes are used, this can not be done without suffering a loss both in milk production and in growth of stock, and also a loss of returns from the other feeds fed. With an abundant supply of leguminous hays, clover, alfalfa, soy bean, or cowpea, a satisfactory balanced ration can be provided by feeding them in conjunction with sorghum or corn silage, or other hays with some corn.

KAFIR, MILLET, AND SORGHUM FOR HAY.

Most of the farms studied had an acreage of sorghum, kafir corn, or millet, as an auxiliary hay crop, because the droughts at times almost entirely ruin the meadow hay crop. In view of the drought-resisting qualities of the sorghums, they undoubtedly will receive much consideration in the future cropping systems of this area. Sudan grass is also worthy of consideration in the arrangement of profitable cropping systems in this area. Where such a practice has been adopted the farmers have available for other purposes a

part of the acreage otherwise devoted to hay. Such areas can be diverted into pasture, which allows a broader and more adequate basis for soil improvement, or they can be used as an aid in growing additional feed or cash crops.

OTHER CROPS.

Field beans, potatoes, and sorghum for sirup represent a minor source of income on many farms. A small area of field beans contributes substantially to the income of some farms. Some operators, however, have been unable to find a satisfactory sale for their crop. The marketing facilities of this region are very limited, and it would be unwise to include a large acreage of a new crop, such as field beans, without first having secured an outlet. Sorghum sirup and potatoes, when sold, represent usually the excess over the amount raised for home consumption, and are sold on the local markets. The principal miscellaneous crops sold are cotton and sweet potatoes raised in the southern part of the area. One operator who raised broom corn sold $390 worth of brooms. Small sales of berries, cherries, garden produce, etc., are also among the miscellaneous sales. The small operator is very much "up against it" for a cash crop in this region. Evidence of this is seen in the amount of receipts from the sales of ties, and receipts for work done off the farm. The entire region is too far north for the profitable production of cotton. However, with intelligent cooperation and the solution of the marketing problem involved, an increased amount of one or more of these minor crops (sirup, field beans, potatoes, and berries) could be sold from many of the smaller farms.

FRUIT.

Apples.—The apple enterprise seems to be very much neglected and on the decline on these farms. A total of 168 acres of apples was found on the farms studied, but this does not include many small areas reported for home use only. The trees in most instances were not cultivated, pruned, or sprayed. Many of the areas in orchards were used for pasture or hay and the trees were dying out. The returns from many of these orchards are of minor importance. The neglect in caring for them was due to the difficulty experienced in marketing previous crops. Only one farmer was found who sprayed and otherwise systematically cared for his orchard, and he, last year, from two acres of trees, sold over $400 worth of apples. They were all sold, however, on a local market, and he was furnishing about all it could handle. (See fig. 10.) There is no doubt, also, that many orchards in this region have been set on soils which are not suited to this purpose, particularly such as are underlain at a slight depth with a hardpan or solid rock.

FIG. 10.—The apple orchard shown in the upper picture received regular cultivation and spraying, and contributed substantially to the farm income of the operator. The peach orchard shown in the lower picture is quite typical of the orchards in the region. Winter-killing and late frosts seem almost to preclude profitable peach production.

Peaches.—Large areas of this region were set to peaches a few years ago. The crop was found to be very unreliable because of the late spring frosts and freezes, and winter freezing and lack of proper care have killed out many of the orchards.

Small fruit.—The production of strawberries and other small fruits which farmers reported very profitable in certain areas in the western part of the State, when undertaken on a small scale, can be commercially profitable only when undertaken in a community where there are sufficient growers to be able to club together and ship in carload quantities or where there is a local demand for the crop.

LIVE-STOCK MANAGEMENT.

The principal factors operating to make live-stock production the main industry in the region are: (1) Transportation facilities are such that, generally speaking, they preclude the marketing of products which are bulky or perishable; (2) the soils of the region are predominantly thin and, owing to the rock content, difficult to cultivate, and quickly deteriorate under continuous grain farming; (3) there is a large amount of wild land which, without cost to the operators, furnishes a varying amount of pasture to live stock of all classes; (4) the lands are adapted to the growing of grasses, and very good improved pastures can be made out of land which is apparently valueless for other purposes; and, (5) a system of farming with live-stock production as its base, if properly carried out, enables the operators to maintain and improve the quality of the cultivated land and furnishes a product which is easily marketed.

All ordinary classes of live stock do well in the region, and at present all are being produced. The raising of cattle is the oldest and most extensively developed branch of the industry. However, a large number of hogs, horses and mules, sheep and goats, and chickens, are raised in the territory. The desirability of not restricting the source of income to one enterprise on the farm has already been pointed out, and examples of individual farms present the favorable results obtained by combining a number of live-stock enterprises. Some of the farms received revenue from all classes of live stock mentioned, and the majority had three or more live-stock enterprises.

As to the combination of live-stock enterprises that will be most profitable on any given farm, local conditions must determine, and to a certain degree the inclination of the operator himself. The scheme of farming, however, should be such as to produce on the farm all feed needed by the live stock maintained and raised, and the farmer should strive constantly to improve the grade of the live stock kept. The higher the grade of live stock raised, the greater will be the returns from the feed consumed, under economic management.

Profits which may be expected from the various classes of live stock vary from year to year, as prices and local conditions vary. In 1917 operators who were successful in raising hogs almost uniformly showed a satisfactory farm income. There was a ready demand at high prices for all hogs offered for sale, an unusually heavy acorn and mast crop was produced in the woods, the feed cost was low for the majority of the hogs raised, and there was no general epidemic of hog cholera in the region. On the other hand, those operators who raised colts found little demand for them, and sales were made with difficulty and at a low price. The margin of farm profit contributed from year to year by the various enterprises varies according to conditions governing production and marketing. An analysis of the receipts shows that cattle and hogs were the live stock which contributed the largest return on these farms.

FIG. 11.—Type of dairy herds kept for production of cream.

The profitable production of cattle in this region depends upon grazing to furnish the bulk of feed required during the summer, with sufficient grain and hay raised on the farm to maintain them during the winter. The bulk of the cattle sales are in the late summer directly off the pastures, though an occasional farmer produces sufficient corn for feeding out a bunch of cattle during the winter. Cream is also being sold from this country in increasing volume. (See fig. 11.)

CREAM PRODUCTION.

This territory is well provided with a market for cream, creameries being located at a number of the more important railway stations, and a few operating at interior points. Practically every little village has one or more cream-receiving stations. It is difficult to overstate the help this has been to many farmers, particularly to those operators of only moderate-sized farms to whom the steady

cash receipts from the sale of cream, though small, was the one factor which enabled them to go ahead with their work of improving and enlarging their farms and building up their herds of live stock, even in some cases preventing actual farm disaster. The sale of dairy products represented a source of cash income for 43 out of the 79 farms for which records were taken. The average amount of sales for farms selling dairy products was $215. On some farms the sales amounted only to an occasional few pounds of butter or cream and on a few farms it constituted the chief source. On many farms the sale of cream was one of the major sources of income.

A few of the farmers had kept records of the amount of their sales of butter fat through the year, and one of the local creameries kindly gave information as to production of a few additional farmers with whom the sale of butter fat was a major source of income. In this way the accurate butter-fat production for seven of the better herds of dairy cows in the region was obtained for the year 1917, as is shown in the following table:

TABLE IX.—*Butter-fat production of seven dairy herds.*

Farm.	Butter fat sold.	Average price per pound.	Value of sales.	Average number of cows.	Average production of butter fat per cow.	
					Quantity.	Value.
	Pounds.				*Pounds.*	
1	980	$0.438	$429	9	109	$48
2	1,563	.421	658	10	156	66
3	2,812	.409	1,152	18	156	64
4	2,525	.424	1,076	18½	136	58
5	996	.391	390	6½	153	60
6	1,563	.421	658	12	130	55
7	640	.40	256	4	160	64
Total	11,079	.417	4,619	78	142	59

Included in the above dairy herds are two herds of Jersey and Guernsey grades, one of grade Holsteins and Jerseys, two of grade Jerseys, one of grade Guernseys, and one containing some grades and also some purebred Jerseys.

The average price per pound received varies slightly, owing to the fact that creameries located at interior points had to pay extra transportation charges, and therefore could not pay quite the prices which prevailed at railroad points; and also to the fact that the quantity of cream sold by the different operators varied during the year, and hence the cream was sold at varying prices.

Since the dairy business is an enterprise comparatively new to this area, the average butter-fat production per cow naturally was very much lower than it should be for the most satisfactory returns. The farmers are becoming much interested in the dairy business, however, and improvements are being made gradually. One operator

sold out his old herd and bought a new one during the year. Another reason for the low average production of many herds was that they are being increased from year to year by the addition of a few young cows. With an average annual butter fat production of only 142 pounds per cow, many farmers have very little chance of making money from the sale of dairy products.

The importance of high production per cow can not be too greatly emphasized. At present a small number of grade and pure bred dairy calves and heifers are being imported into this region at various places. The importation of a few high class pure bred dairy bulls, of proved ability to get high-producing daughters, and the breeding of these bulls to the native cows, is believed to be an economical and logical method of quickly improving the quality of dairy cattle in the region. Mature dairy bulls of proved high class are rather expensive, but they can be bought cooperatively with great advantage to the individual operators cooperating, and at a greatly lessened individual cost. In the selection of a bull the best dairy specialist available should be consulted, and this is especially essential when it is deemed advisable to purchase a bull calf.

The feeding of a ration which supplies the necessary nutritive elements in the proper proportions is essential in all branches of the live-stock business, but especially in dairying. If this is not done the maximum milk production is not obtained, and there is a literal waste of feed because much of the nutritive value of the feeds in a poorly balanced ration is not utilized when eaten. The production of more leguminous hay crops on the farm, as suggested in other parts of this report, with corn or corn and sorghum silage, will furnish the most satisfactory and economical basis for balanced rations in this territory. It is essential that in solving this problem of balanced rations the best available dairy specialist be consulted.

A careful study of the individual cows in the herd should be made, to ascertain the cows which are really profitable and those which are not. This is done by keeping a record of the amount of milk produced by each cow, and periodically testing the butter-fat content of such milk. Cow-testing associations formed under the direction of a competent dairy specialist afford the average dairyman and farmer the most practical method for doing this work.

Many factors affect the desirability of producing and selling dairy products on a given farm. Among these are availability of labor for milking and preparing the product, need of an additional source of cash income, number and character of cows kept, and relative profitableness of other employment for labor. A large proportion of the farms studied had found it advantageous in their organization to sell some dairy products.

Forty per cent of the farms reported cattle losses. There was no epidemic of a contagious disease, and the losses that occurred were probably such as may normally be expected. These losses represented 3.6 per cent of the cattle kept.

HOGS.

Hogs, when raised on the acorns and mast in the woods, furnish perhaps the cheapest meat produced in the Ozarks. This, however, is quite a precarious business, owing to the losses due to predatory animals, stealing, accident, and the uncontrolled epidemics of hog cholera to which hogs on the range are subjected. The acorn and mast crop is also quite variable. In some years there is no crop at all, while during others there is an abundant crop. If there is an acorn crop and the hogs are turned on the range, the additional feeding of some corn is usually found profitable. The corn will induce better gains. The feeding of skim milk, when cream is sold off the farm, affords a profitable opportunity for hog production. Soy beans, and cowpeas planted separately or in corn, and used as grazing crops, also provide good feed for the hogs. Because of the serious losses sustained on the range, many farmers are inclosing woods land, and not allowing the hogs to rove beyond the confines of the farm.

Hogs were kept on 74 of the 79 farms. Thirty-three farms reported losses of hogs, leaving 55.4 per cent of the farms which suffered no such loss. One hundred and sixteen hogs were reported as having died during the year, and 54 small pigs. (These figures do not include losses of pigs at farrowing or of very young pigs lost in the woods.) The year was favorable to hog production, there being no epidemic of cholera or other infectious disease. The percentage of hogs lost to the total number of hogs handled on all the farms was 10.75. The percentage of loss on the farms which suffered losses was much higher. In view of the fact that 41 farms sustained no losses whatever and that many of the farms that conducted an extensive hog business suffered only slight losses, it is evident that by better care this loss could be materially reduced.

HORSES AND MULES.

On some of the farms the raising of colts contributed substantially to the farm income. On other farms, not enough colts were raised to replace losses of work stock. Eleven farms reported losses of horses, 86 per cent of the farms suffering no losses at all. The total number of mature animals that died was 10, and of colts 4. The proportion of horses and mules lost to the number on hand during the year was 3.43 per cent. This, as in the case of cattle, represents a normal and unavoidable loss.

SHEEP.

Sheep are usually raised on farms so situated that they are not subject to destruction by predatory animals. Because of the increased prices, sheep production was a profitable and satisfactory enterprise for the year under study.

Seventeen of the 79 farms studied reported sheep. On 13 of these farms losses were sustained; 19 mature sheep and 17 lambs were reported as having died, representing a loss of 8.9 per cent. (This does not include lambs lost at lambing or while only a few days old.) In the majority of cases the sheep were kept in enclosed pastures, and the farms keeping sheep were, as a rule, in communities where the keeping of sheep has been practiced for some time. Only one sheep was reported specifically as having been killed by dogs, though in the case of a few operators who allowed their sheep to range the woods losses were probably caused by dogs or wolves.

GOATS.

Within recent years the goat has come into a regularly established place on the market, and this fact, together with the great value of the goat in cleaning up land, makes its production especially desirable in the Ozarks. Goats and cattle will pasture the same land to advantage. Only nine farms reported having goats. Eleven and three-tenths per cent of the number maintained on the farm through the year were lost. Of the 12 mature goats and 10 kids which died during the year, dogs killed 6 of the goats and some of the kids. Contrary to a widely held opinion, the goat can not successfully defend itself against vicious dogs, and unless necessary precautionary measures are taken serious losses may be caused by dogs both to mature animals and to unborn and young kids. The goat is an extremely hardy animal, and very valuable, especially in this section, for clearing out underbrush. With proper attention the percentage of loss which occurred in the year considered could be materially reduced and as the goat now has a ready market value besides its great value to this section for keeping the underbrush and sprouts eaten off, such attention would be profitable.

POULTRY.

The sale of poultry and eggs returns a substantial portion of the total cash receipts of many farms. (See fig. 12.) The section is not one of intensive poultry culture. However, the great majority of the farmers keep chickens, which are supported largely by grain and food which otherwise would be wasted. A certain amount of grain is fed directly to the chickens, mainly corn and kafir corn raised for the purpose. A record was obtained from one farm on which the sale

of capons and broilers and eggs brought the major portion of the farm income. The average farmer, however, unless adept at the art of raising chickens, may find it more profitable to subordinate the poultry enterprise. The aggregate amount of chickens and eggs produced in the Ozarks is large, and Springfield, Mo., is recognized as one of the leading poultry markets of the country.

PASTURE.

The rough topography of a large portion of this region makes the grasses of prime importance. The increase in the live-stock industry in the last few years has intensified the need of pastures. In the early years the open range furnished an abundance of grass until late

FIG. 12.—This woman raised and sold 100 capons, 1,000 broilers, and a large number of hens during the year of the survey. In addition, she helped in the milking of 10 cows.

fall. No feed was given during the grazing season, and in the late summer or fall the marketable cattle were sold. The woodlands were burned over each winter to restrain the growth of underbrush and small trees.

As the country became more populous, however, farms became more numerous through the range territory, and the number of cattle and other live stock on the range increased, bringing heavier demands on the pasture. After the erection of more fences and buildings throughout the region the practice of burning over large areas was gradually restricted. Burning the woods was detrimental to the mast and acorn crop, and was gradually discontinued as hog production became an important enterprise.

Farmers in this area are vitally interested in the economic problem of pasture production. Since the introduction of dairying as an important enterprise it has become necessary to keep the cows closer at hand than was possible when they were turned free on the unrestricted range. The net result of this situation is that those farmers who formerly depended upon the range to support the live-stock business now find it necessary to provide supplementary pasture on their own land, and such reorganization had been effected on a number of farms at the time this study was made.

The farms have two sources of possible pasture—one, that part of the tillable area of the farm devoted to pasture in the regular farm rotation; the other, adjoining woodland, properly fenced, on which the growth of grasses is encouraged. On the average farm in this territory feed can be grown to support during the winter more cattle than the tillable area in pasture will support during the summer, and the making of improved pastures out of adjoining woods has become an important undertaking. Undoubtedly the greatest possibilities for expansion of pasture lie within those areas which, because of topographical features and rock obstructions, are suitable for pasture but not suitable for cultivation of crops.

The keeping down of underbrush is the greatest problem involved in this conversion of rough land into improved pastures. It is very difficult for one who has not been in this territory to realize how rapidly and densely underbrush grows with the slightest opportunity, and this growth when not controlled shades the ground so completely that grasses are crowded out. If this growth is kept back, the native grass comes voluntarily and furnishes a fairly good grade of pasture. (See fig. 13.)

Lespedeza (Japan clover), having become naturalized, grows freely, and while it makes a rather late start in the spring, contributes materially during the season to the grazing. White clover grows freely everywhere. These crops in good seasons on fair soil can be made to furnish excellent grazing. Bluegrass and orchard grass thrive, and when planted make a pasture which comes in earlier in the spring, lasts longer in the fall, and has a greater carrying capacity throughout the season than any other.

Much attention has been given the fencing of pasture land in this area during the last few years. From the data submitted by the farmers interviewed, putting up 1 mile of woven-wire fence requires approximately 33 to 38 days of man labor, and 3 to 4 days of horse labor. In addition to this the horses may be used in conveying the men to and from the place of work. The post material ordinarily in use will last about 10 years, if properly seasoned before using. Some farmers clear their fence rows each winter, either by dragging or otherwise, for protection against forest fires. Much land is now

FIG. 13.—Pasturage in the Ozarks. Land such as that illustrated by the upper picture furnishes practically no pasturage. The lower picture shows a good pasture made from land of the same character.

more intensively used for pasture than formerly, through fencing and deadening the growth on woodland areas.

In converting the woodland areas into pasture the first step is killing, or, as it is commonly expressed, "deadening," the large trees and cutting out the underbrush. Where the salable timber has not all been removed, enough tie timber may be utilized to offset a part or all of the cost. The usual method of deadening the trees is to girdle them. Trees of less than 3 inches in diameter are cut down. After deadening the standing timber and cutting off the smaller trees the problem is largely one of controlling the growth of underbrush. This situation is expressed by the local phrase, "There are more trees under the ground than above it." The farmers have found it desirable to deaden the trees during the spring or early summer, as the trees die sooner and more surely, and as girdling 2 to 4 feet above the ground and chopping off the smaller trees at this height reduces the sprouting from the roots. For best results the sprouts should be cut two or three times yearly, depending upon the density of the growth, sometimes for four or five years in succession, though the amount of work involved decreases each year.

Another practice useful in ridding this land of sprouts, and one which eliminates the greater part of the labor, is to pasture goats on it. Since their natural food is leaves and tender sprouts, goats find sufficient forage on the "deadened off" area to thrive and at the same time keep these sprouts from making growth. However, experience has shown that for best results in reducing sprouts the goats should not have access to a great amount of grass. If grass is obtainable goats will not eat the sprouts off thoroughly. Some farmers separate the brush areas from the pastures, and alternate the goats from one to the other during the growing season. In this way the goats are kept in better condition, while aiding materially in brush control. (See fig. 14.) This method is desirable because the goats can be used as a source of profit. There are relatively few goats in the territory, and as their value is now clearly realized they can be bought only with difficulty. The general opinion in the region was that if goats pasture such land for two seasons, the sprouts would be very effectively killed, and very little subsequent work required to keep the growth down entirely. Goats require rather substantial fencing for the most satisfactory results.

Considerable variation exists in the method used in getting a good stand of grass on these lands. Some areas afford sufficient native grass pasture to be of value without the addition of tame grass. However, the sowing of tame grasses has been found desirable. Good pastures have been established both with and without cultivation before seeding.

In seeding land to grass without cultivation or harrowing, the best results have been obtained by first burning the area thoroughly, so that the ground is free from leaves and brush. The seed is sown

FIG. 14.—Above, woods which were deadened a few years ago. Measures were not taken to prevent the growth of sprouts and underbrush, and as a consequence this land has no pasture value to-day. Lower, similar land, on which, after deadening, goats kept the sprouts killed back. This land in a short time will be an excellent pasture.

broadcast, usually during the spring months. Eight to 12 pounds of mixed seeds, consisting of 1 bushel of bluegrass, 1 bushel of timothy, and 3 pounds of white clover seed, are sown to the acre. The first year the grass should not be closely pastured. Some operators allow

cattle to have access to the new pasture, and at the same time to an old, well established pasture sufficient to maintain them. There is then no danger of the cattle cropping the new pasture too closely, but they assist in keeping the young sprouts down. By the third year the newly seeded areas are usually established and capable of furnishing grazing. (See fig. 15.)

The clearing of this land for cultivation before seeding to grass under the ordinary practice usually requires several years. The first year after clearing land the pasture is not materially improved. The second year the native grasses, together with crab grass, beggar lice, lespedeza, and young sprouts, furnish considerable pasture. The

FIG. 15.—Burning off and breaking, a step in the process of clearing land for cultivation or for making an improved pasture. The owner of this land intends to make an improved pasture of it, hence, when the woods were deadened a few years ago some trees were left for shade. He will raise a cultivated crop on it for one year, and in this way finish killing the sprouts and underbrush, after which a mixture of tame grasses and clover will be sown.

second winter the dead and fallen timber is again burned off, and improved conditions provided for the third grazing season. After the third season the native pasture ordinarily will not improve materially; practically all of the dead trees have fallen, and the land can be placed in fair shape for breaking. About the fourth season the land is broken, and a cultivated crop, corn usually, is planted. Following this crop a mixture of grass seed is sown broadcast, and harrowed in. Good results have followed from sowing 10 to 15 pounds per acre of a mixture—white clover 1 pound, red clover 2 pounds, orchard grass 5 pounds, and bluegrass 5 pounds. Under favorable conditions, by the middle of the following summer these seedings should furnish some pasture.

One great advantage of pasture made from the tame grasses is that they furnish grazing earlier in the spring, and for about four to six weeks longer in the fall than native grass pastures.

THE ORGANIZATION AND PROFITS OF INDIVIDUAL FARMS.

To be profitable a farm should follow the type of farming best adapted to its conditions, should be efficient in the use of both man and horse labor, adequately yet economically equipped and as good as or better than the average farm of its type in size of business, yield of crops, and returns from live stock. The land must be capable of growing crops for sale or crops to be utilized in producing something which can be sold. Crops which are not in either of these classes will not profit the producer, even though the land is suited to their production, nor will their production be profitable unless they are utilized when produced. Thus, though a farmer has land suitable to the production of a perishable crop requiring a highly organized marketing system of distribution, if he is located in a section where such an organization is not available and has not the ability or the means to provide it, it would not pay him to produce such a crop. The land operated may also be too high in price to produce profitable returns on the investment under the type of farming to which it is best adapted.

Many factors cause a variation in the profit from various farm products from year to year. One year a product may be produced at a profit, the next at a loss, or the attempt to produce it may result in a failure. The farming business, however, has to go on each year, and in regions where wide variations both in yields and in prices exist the farmer may have a greater assurance of an income each year by having a combination of revenue-producing enterprises. Should one or two fail, the income from the others will compensate the loss. These enterprises should be so organized that labor may be utilized as effectively as possible throughout the year.

The statement and analysis of combined farms afforded the opportunity of observing what enterprises, considering the region as a whole, were being exploited and to what extent they were productive of revenue.

In figure 16 is shown the labor income (each bar represents the labor income of a farm) of each of the valley and level-upland farms and each of the hilly farms. The farms are arranged according to the acreage devoted to crops, beginning with the farm having the smallest acreage of crops. From this chart it will be seen that of the valley and level upland group only one farmer earned over $2,000 labor income, and he had next to the largest acreage in crops. Fifteen had over $1,000, and eight earned no cash wage for their year's labor and less than 5 per cent on the capital invested. Of the hilly farms,

only two made $1,000 or over, and six earned no cash labor income and less than 5 per cent on the capital invested. As previously pointed out, each farmer had, in addition to his labor income and interest on investment, house rent, home-grown food products, and fuel furnished by the farm, factors that contribute considerably to the family living.

The labor income data shown in this figure and in the following data for 10 individual farms serve to emphasize the variation in

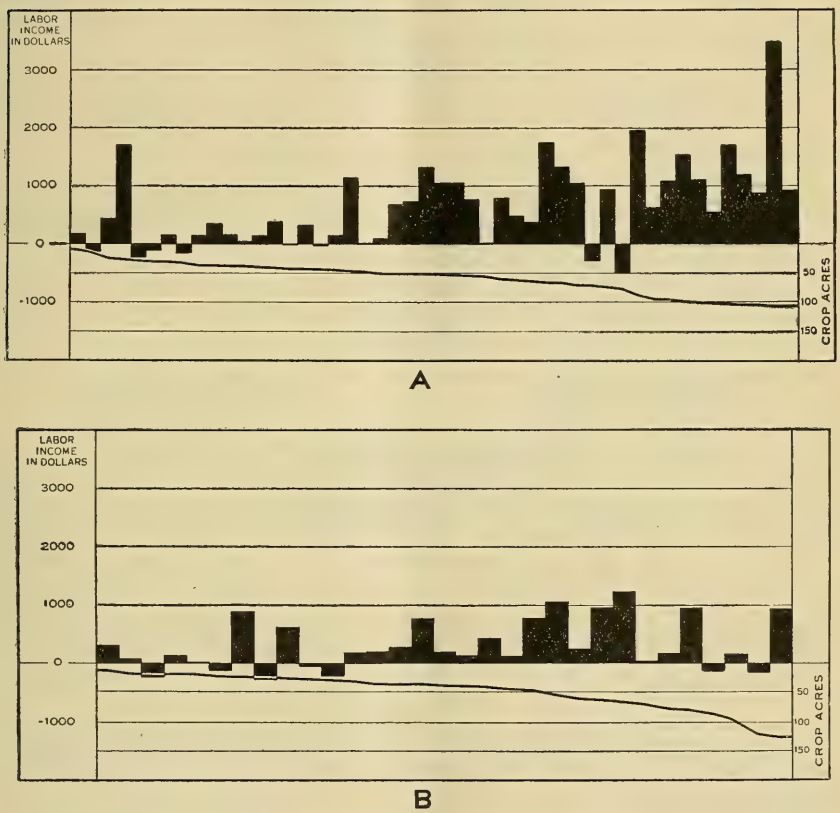

FIG. 16.—Relation of size of farm to labor income. (A, 48 valley and level-upland farms; B, 31 rolling and hilly upland farms.) Each bar represents the labor income of one farm, beginning at the left with the smallest farm.

returns within a year. Some farmers are making good labor incomes, while others fail to receive anything for their year's wages above the supplies furnished the family by the farm. In farming, as in any other occupation, the more satisfactory returns are for those who practice the best methods. The wide range in labor income as shown by a study of each farm gives evidence that the man of skill, industry, and good judgment is the one who receives the highest rewards in operating a farm.

In the following analysis of the business of 10 individual farms, opportunity is afforded for a study of the factors which determined their success or failure for the year. Along with the analysis of each farm business is a brief discussion of the farm considered. Each farm here analyzed is deserving of careful study.[1]

FARM NO. 1.

DISTRIBUTION OF FARM AREA.

Crop area	acres	23
Woods and waste	do	10
Pasture	do	7
Total farm area	do	40

DISTRIBUTION OF CAPITAL.

Land and buildings	$500
Live stock	165
Machinery	57
Feed and cash	250
Total capital	972

ACREAGE AND YIELD OF CROP.

Crop.		Total yield.	Acres.
Corn	bushels	110	12
Rye	do	35	6
Oats and millet hay	tons	3	3.75
Potatoes	bushels	40	.50
Fruit			.75

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	1	2	1
Calves		2	1
Horses	2		
Brood sows		1	
Hogs		1	6

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Corn	bushels	15	$22
Cattle			35
Hogs			37
Total receipts			94

DISTRIBUTION OF EXPENSES.

Family labor	$100
Repairs to machinery	13
Seed	28
Other expenses	14
Depreciation, machinery and buildings	18
Total expenses	173

Farm income (difference between receipts and expenses)	−$79
5 per cent interest on capital	49
Labor income (loss)	−128

Farm No. 1 is a small farm in a rough and rocky section. This farm gives an illustration of the hardships and difficulties which confront an inexperienced operator with limited means attempting to establish a small farm on the poorer upland soils of this region.

This operator bought his farm in 1908, using practically all of his money in the purchase of the 40 acres. In the 10 years following he suffered disaster a number of times, from crop failure due to drought and from loss of live stock. Being a mechanic, he returned to St. Louis after each disaster and worked until he had accumulated enough money to purchase more work horses and supplies. In this way, he has spent 4 of the 10 years preceding 1918 in St. Louis, his wife and two small children living on the farm in his absence, but unable to do much farming. He had worked the greater part of 1916 in St. Louis, and, as he said, returned for the fifth start. At the beginning of the farm year covered by this study he had live stock consisting of 1 cow and 2 horses. He spent four months out of the year in St. Louis and with his savings purchased for $215, 2 cows, 2 calves, and 2 hogs.

[1] The first five of these farms are rolling and hilly farms, and the next five are valley and level-upland farms.

The total year's income on this farm was only $94, while the expenses were $173. Not having raised any crops for sale, and having practically no live stock, he has no chance of making a farm income after paying the year's expenses and allowing the value of labor performed by his family.

FARM NO. 2.

DISTRIBUTION OF THE FARM AREA.

Crop area	acres	24
Woods and waste	do	19
Pasture	do	15
Total farm area	do	58

DISTRIBUTION OF CAPITAL.

Land and buildings	$1,800
Live stock	392
Machinery	162
Feed and cash	80
Total capital	2,434

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	500	20
Cane	gallons	225	4

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	1		
Calves			1
Horses	1		
Mules	2		1
Sheep		6	
Brood sows	1	2	
Hogs	12	9	22
Poultry	20		49

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Corn	bushels	267	$336
Sorghum sirup	gallons	175	105
Sorghum seed			70
Cattle			29
Colts			90
Sheep and wool			3
Hogs			443
Poultry and eggs			47
Labor off farm			20
Total receipts			1,143

DISTRIBUTION OF EXPENSES.

Repairs to machinery	$10
Repairs to building and fences	25
Feed	50
Other expenses	28
Depreciation, machinery and buildings	37
Total expenses	150

Farm income (difference between receipts and expenses)	$993
5 per cent interest on capital	122
Labor income	871

This is a small farm situated on good upland soil. It is located in a section where an abundance of free range is available. Corn and sorghum were the only crops planted. The 4 acres of sorghum was used partly for sirup, and the rest for hay after thrashing the seed. The live stock consisted of 1 cow, 1 old mare, 2 mules, 1 sow, and 12 shotes, and a small flock of chickens. A calf was raised and sold, also a valuable mule colt.

This farmer found the hog business quite profitable and increased his enterprise on his farm by the purchase of 2 sows and 9 shotes. The year's revenue from hogs was $443. The abundant pasturage available enabled the farmer to produce hogs mainly on the mast on the range, and the work stock and cow required very little feed in addition to pasture, with the result that 267 bushels of the corn was sold, also $105 worth of sorghum sirup and $70 worth of sorghum seed. The expenses were not heavy. However, it should be noted that it was found necessary later to buy $50 worth of feed.

All the labor on this farm was performed by the operator himself, and for the year's labor the farmer had $871 after paying all expenses and allowing 5 per cent interest on the capital invested.

FARM NO. 3.

DISTRIBUTION OF FARM AREA.

Crop area	acres	95.5
Woods and waste	do	36.5
Pasture	do	51.0
Total	do	183.0

DISTRIBUTION OF CAPITAL.

Land and buildings	$5,000
Live stock	1,546
Machinery	443
Feed and cash	333
Total	7,322

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	555	22
Potatoes	do	85	1.5
Wheat	do	165	15
Rye	do	10	.75
Oats	do	102	5
Hay	tons	28	50
Apples (in pasture)			18
Garden			1.25

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	8		
Heifers	7		
Calves	5	2	11
Bulls	1		
Steers	7		
Horses	5		
Sheep	13	1	
Lambs	10		10
Brood sows	2		
Hogs			21

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Potatoes	bushels	6	$9
Wheat	do	66	136
Oats	do	48	41
Apples			20
Corn	bushels	75	105
Hay			23
Cattle			635
Dairy products			133
Colts			50
Sheep and wool			147
Swine			486
Total receipts			$1,785

DISTRIBUTION OF EXPENSES.

Hired labor	$67
Family labor	600
Repairs to machinery	33
Repairs to building and fences	32
Feed	270
Seed	46
Fertilizer	40
Other expenses	102
Depreciation, machinery and buildings	74
Total expenses	1,264

Farm income (difference between receipts and expenses)	$521
5 per cent interest on capital	366
Labor income	155

This is one of the larger upland farms with a rolling topography. It was poorly organized, as will be observed by a study of the acreage and production of crops, amount and returns from live stock, the size of the feed bill, and the amount of both man and horse labor used. Quite a large area was in meadow hay. Eighteen acres of apples had also been planted, but the trees were being allowed to die out, and the acreage last year was cut for meadow hay. Quite a large amount of live stock was kept. Cattle sales amounted to $635, and furnished the largest single source of income, with hogs, $486, the next largest. Revenue was also obtained from dairy products, colts raised, sheep, wool, crops and fruit.

If this farmer were to pay his family the value of their year's work at $600 and pay interest on his investment at 5 per cent he would have left for his own year's labor

only $155. Compare with No. 4 as to organization of crop land, amount of labor used, feed purchased, live-stock production, and amount of work stock kept, and it will be easy to detect why this farmer got only $155 as labor income for his year's labor while No. 4 got over $1,000 for his.

FARM NO. 4.

DISTRIBUTION OF FARM AREA.

Crop area	acres	55
Woods and waste	do	70
Pasture	do	35
Total farm area	do	160

DISTRIBUTION OF CAPITAL.

Land and buildings	$5,600
Live stock	1,454
Machinery	647
Feed and cash	117
Total capital	7,818

DISTRIBUTION OF CROP AREA.

Crop.		Total yield.	Acres.
Corn	bushels	500	17
Corn for silage	tons	60	8
Kafir corn	do	1.5	2
Wheat	bushels	115	9
Oats	do	117	3.5
Hay	tons	9	12
Apples			2
Garden			1.5

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	9		
Heifers	3	2	
Calves	8		13
Horses	3		
Oxen	1		
Colts	1		2
Sheep	6	1	
Lambs	8		8
Brood sows	1	1	
Hogs	3		10
Poultry	65		50

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Wheat	bushels	25	$50
Hay	ton	1	17
Corn	bushels	175	262
Oats	do	15	11
Dairy products			400
Cattle			615
Colts			85
Sheep and wool			230
Hogs			376
Poultry and eggs			177
Total receipts			2,223

DISTRIBUTION OF EXPENSES.

Family labor	$400
Repairs to machinery	15
Repairs to buildings and fences	35
Feed	23
Seed	27
Other expenses	73
Depreciation, machinery and buildings	100
Total expenses	673

Farm income (difference between receipts and expenses)	$1,550
5 per cent interest on capital	391
Labor income	1,159

This is a highland farm with rolling topography, which was operated quite successfully. Fifty-five acres of crops were raised, consisting of corn, wheat, oats, kafir corn, meadow hay, apples and garden crops. It was not necessary to purchase any feed in addition to that raised, which aided materially in holding the expenses to a minimum. Dairy products, calves, colts, wool and lambs, hogs, poultry, and general crops were produced upon this farm. All these enterprises brought in some revenue, the largest single source being cattle. The total gross farm income was $2,223. No colts or lambs were sold, the increases being kept on the farm to increase the size of the business for the coming year. No outside labor was hired, and the single item of largest expense was $400 for family labor. Deducting expenses, a net income of

$1,550 was left, of which $1,159 was the operator's labor income for his year's work, which is a very successful showing under the conditions existing in this area.

This farm was so organized that the farmer could pay his family labor for the work performed, pay interest on investment, and at the same time be well paid for his own year's work.

FARM NO. 5.

DISTRIBUTION OF FARM AREA.

Crop area	acres	67
Woods and waste	do	293
Pasture	do	70
Rented out	do	10
Total farm area	do	440

DISTRIBUTION OF CAPITAL.

Land and buildings	$4,000
Live stock	2,170
Machinery	643
Feed and cash	590
Total capital	7,403

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	700	20
Wheat	do	300	17
Hay	tons	10	15
Millet hay	do	4	3
Alfalfa	do	13	7
Apples	bushels	400	4
Garden			1
Peas [1]	bushels	8	2

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	12		
Heifers	3		
Calves	8	2	14
Bull	1		
Steers	15		
Horses	5		
Colts	1		1
Brood sows	4		
Hogs	5		31
Poultry	78		99

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Wheat	bushels	225	$428
Apples	do	400	400
Hay	tons	2	40
Corn	bushels	200	350
Dairy products			76
Cattle			850
Colts			60
Hogs			342
Poultry and eggs			136
Total receipts			2,682

DISTRIBUTION OF EXPENSES.

Hired labor	$105
Family labor	396
Repairs to machinery	50
Repairs to buildings and fences	90
Feed	49
Seed	86
Fertilizer	72
Other expenses	153
Depreciation, buildings and machinery	88
Total expenses	1,089

[1] Second crop.

Farm income (difference between receipts and expenses)	$1,593
5 per cent interest on capital	370
Labor income	1,223

This was perhaps the most successfully operated of all the hilly-upland farms from which records were obtained, and in this connection it is interesting to note that when this operator moved to the farm 20 years ago he bought it from a man who had made a failure of its operation.

The present operator has taken in more land than was under cultivation when he first bought it and has expended an immense amount of work in picking up and hauling stones off the place. For hay he had 15 acres of meadow, 7 acres of alfalfa, and 3 acres of millet. Two acres of cowpeas were planted in the apple orchard. The other crops consisted of 20 acres of corn and 17 acres of wheat. The live stock consisted of 12 cows, 15 feeding steers, 5 horses, 1 colt, 4 brood sows, and other young

stock, and a flock of chickens. No live stock was lost during the year. He has for years practiced a regular system of crop rotation and pasturage and the use of stable manure on his land, and good yields were obtained. He also cultivates and sprays his apple orchard carefully and obtains good yields. Apple sales of $400, wheat $428, and net sales of cattle amounting to $850 were his largest sources of cash receipts. Hogs contributed $342 to the farm income. Revenue was also obtained from the sale of dairy products, raising colts, poultry, and other sources.

The gross farm income amounted to $2,682, total expenses of $1,089 deducted from this left a net income of $1,593, of which $1,223 was the operator's labor income for his year's work.

FARM NO. 6.

DISTRIBUTION OF FARM AREA.

Crop area	acres	37
Waste and woods	do	19
Pasture	do	21
Total farm area	do	77

DISTRIBUTION OF CAPITAL.

Land and buildings	$5,000
Live stock	626
Machinery and tools	160
Feed and cash	64
Total capital	5,850

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	375	8
Wheat	do	100	10
Oats	do	230	10.5
Barley	do	65	3.5
Hay	do	2	2
Apples			3

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	3		
Bull	1		
Heifer	1		
Calves	2		4
Horse	7		
Colts			6
Boars	1	1	
Brood sows	2		
Hogs	6	8	15
Chickens	45		18

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Corn	bushels	54	$96
Oats	do	60	45
Wheat	do	50	95
Barley	do	2	4
Dairy products			40
Cattle			151
Colts			215
Hogs			268
Poultry and eggs			34
Total receipts			948

DISTRIBUTION OF EXPENSES.

Extra hired labor	$12
Family labor	150
Repairs to machinery	10
Repairs to fences	10
Feed	160
Seed	18
Other expenses	124
Depreciation, machinery and buildings	40
Total expenses	524

Farm income (difference between receipts and expenses)	$424
5 per cent interest on capital	292
Labor income	132

This farm of 77 acres had live stock at the beginning of the year consisting of 3 cows; 4 calves, yearlings, and heifers; 7 mares, 2 sows and 7 other hogs. There were 8 acres of corn and 24 acres of wheat, oats, and barley; 2 acres of hay, and 21 acres of pasture. Receipts from hogs were low. Some dairy products were sold. Six colts were born during the year but were of a small, inferior breed and of low value. Most of the crops raised were fed on the place, and, in addition, $160 was spent for feed. Feed produced by the combination of crops was not as great as could have been

obtained by planting more corn and forage crops, and returns from stock were not commensurate with the value of the feed consumed, especially from the great number of horses. This farm had for three years belonged to the present owner, who stated that at the outset he had $2,000 cash, in addition to that used in purchasing and equipping the farm, but had used this entire amount in addition to the farm returns for the three years' living. The year's analysis of the business shows quite clearly why this was necessary. His horse enterprise is large and unprofitable.

FARM NO. 7.

DISTRIBUTION OF FARM AREA.

Crop area	acres	56
Waste and woods	do	109
Pasture	do	35
Total farm area	do	200

DISTRIBUTION OF CAPITAL.

Land and buildings	$9,500
Live stock	1,761
Machinery and tools	505
Cash	100
Total capital	11,866

ACREAGE AND YIELD OF CROPS.

		Total yield.	Acres.
Corn	bushels	200	4
Corn and soy beans for silage	tons	100	10
Wheat	bushels	96	10
Rye	do	32	4
Rye (pastured)			4
Oats	bushels	128	4.5
Kafir corn (seed)	do	10	2
Hay	tons	4	5
Soy beans	do	15	6
Sorghum	gallons	40	1.5
Cane after oats	do	10	4.5
Apples			4
Blackberries	crates	44	1

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	10		
Heifers	9		
Calves			13
Bulls	1	¼	
Horses	3		
Mules	1		
Mule colt	1		
Boar	1		
Brood sows	2		
Hogs	7		19
Chickens	125		86

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Wheat	bushels	80	$160
Rye	do	2	4
Oats	do	40	30
Hay	tons	4	48
Blackberries	crates	41	43
Dairy products			658
Cattle			374
Colts			25
Hogs			252
Poultry and eggs			118
Wood			12
Total receipts			1,724

DISTRIBUTION OF EXPENSES.

Hired labor	$40
Family labor	500
Repairs to machinery	22
Repairs to fences	7
Feed	212
Seed	46
Other expenses	166
Depreciation, machinery, and buildings	120
Total expenses	1,113

Farm income (difference between receipts and expenses)	$611
5 per cent interest on capital	593
Labor income	18

This farm had an improved area of 91 acres. The stock on hand at the beginning of the year consisted of 10 cows, 9 heifers, and 1 bull; three horses, 1 mule, and 1 colt; 2 sows and 8 other hogs, and a flock of chickens. Fifty-six acres of crops were raised and good yields obtained.

This represents one of the farms where dairying receives considerable attention. When the present operator purchased this farm, six years ago, it was in a badly run-down condition, and his good management in inaugurating a cropping system and

the dairy industry has been the means of building up the farm until he now gets yields far above the average of the region. He covers 14 acres a year with 7 tons of manure per acre. The cows of a dairy herd were kept for dairy purposes (steer calves not being raised), and consumed most of the feed raised on the place. In addition, $213 worth of feed was bought. The average annual production of butter fat per cow was only 130 pounds, an inadequate return for the feed consumed. In consequence, as the capital investment was rather high, a labor income of only $18 was earned by the operator. Increasing the production of the dairy cows is of prime importance on this farm.

FARM NO. 8.

DISTRIBUTION OF FARM AREA.

Crop area	acres	52
Woods and waste	do	25
Pasture	do	43
Total farm area	do	120

DISTRIBUTION OF CAPITAL.

Land and buildings	$7,800
Live stock	1,812
Machinery and tools	986
Cash	200
Total capital	10,798

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	800	20
Wheat	do	230	10
Oats	do	160	4
Hay	tons	16.5	11
Alfalfa	do	2	2
Apples			2
Peaches			1
Garden			2

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	9		
Heifers	4		
Steers	4		
Calves	8		12
Bulls	1		
Horses	3		
Colts	1		1
Sheep	9		
Lambs	11		11
Brood sows	2		
Hogs			24
Chickens	100		50

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Corn	bushels	100	$150
Wheat	do	180	360
Oats	do	25	23
Hay	tons	1	27
Dairy products			658
Cattle			455
Colts			65
Sheep and wool			217
Hogs			797
Poultry			255
Total receipts			3,007

DISTRIBUTION OF EXPENSES.

Hired labor	$44
Family labor	600
Repairs to machinery	50
Repairs to buildings	75
Feed	100
Seed	38
Fertilizer	54
Other expenses	92
Depreciation, building, and machinery	105
Total expenses	1,158

Farm income (difference between receipts and expenses)	$1,840
5 per cent interest on capital	549
Labor income	1,309

This farm contained 95 acres of improved land. It is interesting to compare this farm with farm No. 7 as to crop area, size of business, and returns. The stock on hand at the beginning of the year consisted of 9 cows and 17 head of other cattle, 3 horses, and a colt, 2 brood sows, 20 sheep and lambs, and a flock of chickens. Manure was saved

and applied carefully, and a 3-to-4-year rotation followed. Most of the crops raised, except the wheat, were fed on the place. All calves were raised. Two litters of pigs were raised from 1 sow, one litter from the other sow, and the sale of these pigs furnished an especially good source of income. Income was derived from all other classes of live stock kept, with over 20 per cent of the total receipts from sales of crops. Both a good farm income and labor income were earned. The family labor on this farm, valued at $600, was done by the operator's daughters, who found the work both profitable and pleasant. (See Fig. 17.) This farm is well organized and unusually well diversified.

FARM NO. 9.

DISTRIBUTION OF FARM AREA.

Crop area	acres	122
Woods and waste	do	98
Pasture	do	91
Total farm area	do	311

DISTRIBUTION OF CAPITAL.

Land and buildings	$10,260
Live stock	3,153
Machinery and tools	673
Feed and cash	376
Total capital	14,462

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	1,155	33
Wheat	do	385	29
Oats	do	300	12
Hay	tons	20	30
Cowpeas (hogged)			12
Orchard, garden, etc.			6

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	13		
Steers	8		
Heifers	9		
Calves			13
Horses	4		
Mules	2		
Colts	3		2
Ewes	29		
Lambs			23
Brood sows	4		
Hogs	43		44

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Corn			$329
Winter wheat	bushels	295	561
Hay	tons	1	12
Dairy products			150
Cattle			372
Colts			140
Sheep and wool			466
Hogs			915
Poultry and eggs			40
Total receipts			2,985

DISTRIBUTION OF EXPENSES.

Hired labor	$20
Family labor	180
Repairs to machinery	35
Repairs to building and fences	33
Seed	32
Fertilizer	60
Other expenses	111
Depreciation, buildings and machinery	107
Total expenses	578

Farm income (difference between receipts and expenses)	$2,407
5 per cent interest on capital	723
Labor income	1,684

This is a relatively large farm, containing 213 acres of improved land. The live stock at the beginning of the year consisted of 13 cows and 23 other cattle; 6 horses and mules, 3 colts; 29 sheep and lambs; 4 brood sows and 43 pigs. The sale of hogs constituted the chief source of income, followed in the order named by sale of crops, sheep, cattle, dairy products, colts, and poultry. Among the crops were 12 acres of cowpeas hogged off. Wheat was the important cash crop. The farm income and labor income earned were very satisfactory.

FARM NO. 10.

DISTRIBUTION OF FARM AREA.

Crop area	acres	90
Woods and waste	do	17
Pasture	do	85
Total farm area	do	192

DISTRIBUTION OF CAPITAL.

Land and buildings	$6,000
Live stock	3,331
Machinery and tools	474
Feed and cash	340
Total capital	10,145

ACREAGE AND YIELD OF CROPS.

Crop.		Total yield.	Acres.
Corn	bushels	900	25
Wheat	do	238	17
Oats	do	290	9
Hay	tons	15	30
Millet hay	do	5	7
Garden			2

NUMBER OF LIVE STOCK.

Class.	Beginning of year.	Purchased.	Produced.
Cows	11	2	
Heifers	7		
Calves	7		11
Bulls	1	1	
Steers	2		
Horses	4	1	
Mules	4	1	
Colts	2		2
Sheep	28		
Lambs	34		21
Brood sows	3	1	
Hogs	10		16
Chickens	80		75

DISTRIBUTION OF RECEIPTS.

Source.		Amount sold.	Value.
Corn	bushels	425	$520
Wheat	do	138	276
Oats	do	70	42
Dairy products			260
Cattle			543
Horses, mules, and stallion fees			845
Sheep and wool			575
Hogs			191
Poultry and eggs			282
Total receipts			3,534

DISTRIBUTION OF EXPENSES.

Hired labor	$300
Family labor	300
Repairs to machinery	40
Repairs to buildings and fences	30
Feed	60
Seed	28
Fertilizer	23
Other expense	193
Depreciation, building and machinery	85
Total expenses	1,059

Farm income (difference between receipts and expenses)	$2,475
5 per cent interest on capital	507
Labor income	1,968

The operator of this farm carried on a considerable live-stock business, as is shown by the number and value of stock on hand at the beginning of the year. In addition, he bought a few more cattle, horses, and hogs during the year. Horses and mules afforded his chief source of income. Over 40 per cent of the total investment was in working capital. Income was contributed by all classes of stock, and corn, wheat, and oats were sold to the extent of $838. This farm was in a section with an abundance of free range pasture.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 942

Contribution from the Bureau of Animal Industry

JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER May 4, 1921

POISONOUS PROPERTIES OF THE WHORLED MILKWEEDS ASCLEPIAS PUMILA AND A. VERTICILLATA VAR. GEYERI.

By C. Dwight Marsh, *Physiologist in Charge of Investigations of Stock Poisoning by Plants*, and A. B. Clawson, *Physiologist, Pathological Division.*

PURPOSE OF PAPER.

As stated in Department Bulletin 800, "The Whorled Milkweed (*Asclepias galioides*) as a Poisonous Plant" (pp. 5 and 6), there are certain other species of whorled milkweed closely related to *A. galioides*. These species have a fairly wide distribution in the United States and it is a matter of considerable interest to know whether they have poisonous properties similar to those found in *A. galioides*. While hitherto these other species have not been examined experimentally, there has been good reason to suspect some of them of being connected with losses of livestock.

Experimental work on two species, *A. pumila* and *A. verticillata* var. *geyeri*, has now demonstrated their toxic character, and also has brought out quite definitely the character of their action as compared with *A. galioides*. In this bulletin are summarized the results of the experimental work on these plants. The work accomplished indicates that *A. pumila* is about one-third as toxic as the very poisonous *A. galioides*, and *A. verticillata* var. *geyeri* is less poisonous, being about one-tenth as toxic as *A. galioides*.

DESCRIPTION OF ASCLEPIAS PUMILA.[1]

Asclepias pumila (Pl. I) may be called low whorled milkweed, or Great Plains whorled milkweed. The stems, which are often

[1] In conformity with the cooperative arrangement between the Bureau of Plant Industry and the Bureau of Animal Industry in regard to investigations of poisonous plants, the material on which this paper is based was collected by W. W. Eggleston, Bureau of Plant Industry, and the description of *Asclepias pumila* and that of *A. verticillata var.* geyeri, on page 10, were prepared by him. Mr. Eggleston has made a detailed study of the systematic position and distribution of these plants, which it is expected will be published later.

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branching, are 3 to 12 inches high, tufted, and puberulent. The main root is horizontal, branching, and produces adventitious buds.

Figure 2 of Plate I shows plants growing from adventitious buds on the root. The leaves, which are 1 to 2 inches long, are sessile, numerous, crowded, and irregularly alternate to verticillate, linear-foliform, revolute, and scabrous-puberulent. The flowers are in terminal branching umbels, few to many flowered, with short peduncles, and are scabrous-puberulent. The greenish-white corolla has oblong lobes and white oblong hoods, which are hastate-sagittate in back view and shorter than the horn. The follicles are erect, puberulent and 1½ to 3 inches long. The plant is found in adobe draws, in

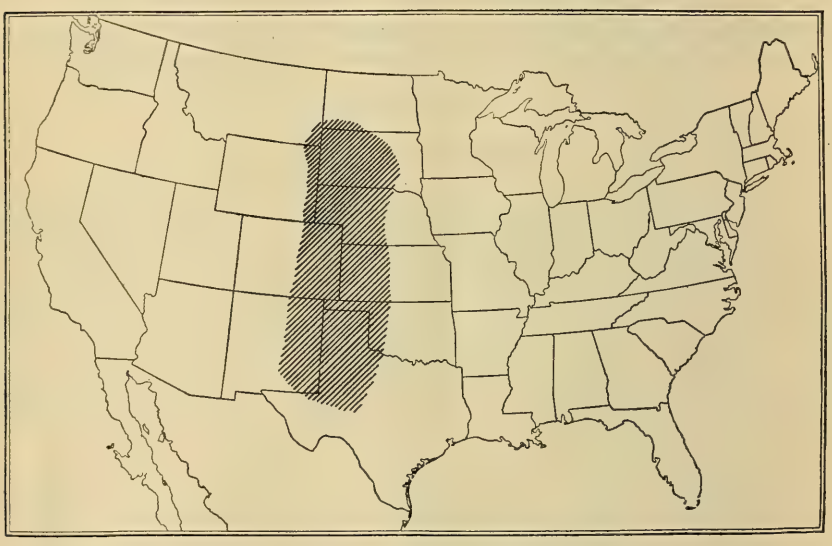

FIG. 1.—Distribution of *Asclepias pumila*.

dry plains, and in foothills from southeastern Montana and southwestern North Dakota to the Texas Panhandle and central New Mexico. It is most abundant on the plains of Colorado.

Text figure 1 shows the distribution of the plant. Although it has a root system and seeds similar to *Asclepias galioides*, it has not spread widely. It usually is scattered in small patches in draws.

The systematic position of *Asclepias pumila* is discussed in United States Department of Agriculture Bulletin 800, pages 5 and 6.

EXPERIMENTAL WORK WITH A. PUMILA.

All experimental work which was carried on in the summer of 1919 was with sheep, and the material in all cases was administered by the balling gun.

The plant material used was collected in Yuma County, Colo.—a part of it in the town of Wray. The material was dried, but in the experimental work was estimated as green plant, 72 per cent being allowed for loss of weight in drying.

The following table is a summarized account of the experiments, 22 in number:

TABLE 1.—*Summary of feeding experiments with Asclepias pumila (air-dried plant fed with balling gun).*

Animal.		Date of feeding.	Part of plant used.	Weight of plant (estimated as green plant) for 100 pounds of animal.	Remedy used.	Result.	Place and date of plant collection.
Designation.	Weight.						
	Pounds.	1919.		*Pounds.*			
Sheep 532	98	July 23	Leaves and stems.	0.150	None	Not sick	Wray, Colo., July 5, 1919.
Sheep 514	135	July 25	do	.197	do	do	Do.
Sheep 539	99	July 26	do	.295	do	do	Do.
Sheep 547	89.5	July 28	do	.402	do	do	Do.
Sheep 546	100	July 29	do	.787	do	Symptoms	Do.
Sheep 482	122.5	Aug. 1	do	.787	do	do	Do.
Sheep 486	135	Aug. 5	do	.827	do	Sick	Do.
Sheep 530	95	Aug. 8	do	.866	do	Symptoms	Do.
Sheep 536	114	Aug. 11	do	.866	do	Somewhat sick	Do.
Sheep 539	104	Aug. 15	do	.905	do	Symptoms	Do.
Sheep 552	94.5	Aug. 18	do	.984	do	Sick	Do.
Sheep 516	81.5	Aug. 24	do	.984	do	do	Yuma County, Colo., Aug. 12, 1919.
Sheep 547	95.5	Aug. 29	do	1.063	Eserin and pilocarpin.	do	Do.
Sheep 554	104.5	Sept. 2	do	1.181	None	do	Do.
Sheep 546	101.5	Sept. 6	do	1.339	do	do	Do.
Sheep 512	124.5	Sept. 11	do	1.496	do	Symptoms	Do.
Sheep 520	102	Sept. 15	do	1.693	do	Sick	Do.
Sheep 539	105.75	Sept. 17	do	.787	do	Symptoms	Do.
Sheep 516	80.75	Sept. 19	do	1.850	do	Sick	Do.
Sheep 542	111.5	Sept. 23	do	1.968	do	do	Do.
Sheep 519	85	Sept. 25	do	2.165	do	Died	Do.
Sheep 547	99	Sept. 27	do	2.559	do	do	Do.

TYPICAL CASE OF SHEEP 547.

Sheep 547 was a ewe which had been used for other experimental work earlier in the season, but was in good condition when on July 28, 1919, she was selected for feeding with *Asclepias pumila.* At that time she weighed 84 pounds. At 3.10 p. m., 0.402 pound green weight of the plant per 100 pounds of animal was given by the balling gun. This produced no effect.

On August 29, at 6.04 p. m., the sheep was given, by the balling gun, 1.063 pounds of plant, green weight, per 100 pounds of animal. At this time she weighed 95.5 pounds. On August 30, at 7.25 a. m., the pulse was 112 and weak, the respiration 12, rather deep, with somewhat forcible expirations. She was humped up, with the head held high, and showed weakness in the hind legs. Later in the day

she staggered when walking, appearing "stiff behind." During this day and August 31 her condition remained much the same. She was depressed, held the head high much of the time, and staggered or wabbled when walking. On September 1 the uncertain movement in walking had largely disappeared, but she was rather inactive. On September 2 she had apparently entirely recovered. There was no elevation of temperature during this sickness.

This animal received several doses of eserin and pilocarpin, but apparently the remedy had no beneficial effect.

On September 27 another experimental feeding was made, the sheep at this time weighing 99 pounds. She received 2.559 pounds, green weight, per 100 pounds of animal, between 3.20 and 3.50 p. m. On September 28, at 7.40 a. m., she stood with head held high and nose extended, was somewhat bloated, and unsteady on her feet, this latter characteristic being most marked in the hind legs.

At 9.09 a. m. the pulse was weak, respiration irregular, and the animal staggered badly. This condition continued, the weakness and discomfort increasing. Plate II, figure 1, taken at 10.46 a. m., when she was somewhat salivated, illustrates the general condition. At 11.15 a. m. she was found down and unable to rise. She went into a spasm at 11.21, with the head drawn toward the breast. Another spasm followed at 11.35, the head being first drawn down and then thrown back in the position of opisthotonos.

The pulse at this time was rapid and weak and the respiration labored. Until about 6 p. m. there was an almost continuous series of spasms, the time between successive ones rarely being as much as 5 minutes. At noon running movements appeared in connection with the spasms. The spasms were very violent for the most part, opisthotonos being very marked and sometimes the head was struck upon the ground with great violence. Plates II and III show some of the attitudes assumed between 11.36 a. m. and 1.45 p. m.

About 6 p. m. the animal became comparatively quiet, and remained so until 8.50 p. m., when a series of continuous spasms commenced, which were terminated by death at 9.23 p. m.

Most of the time the pulse was rapid and weak. The respiration varied, sometimes being very rapid, and at others slower and labored. Text figure 2 shows the curve of temperature. It will be noted that there were three high periods, the maximum, 109.6 F., being at the time of death. The low period between 6 and 8 p. m. is correlated with a time of comparative quiet, but this is not true of the 3 o'clock low, for the spasms were practically continuous during the afternoon. The immediate cause of death was respiratory paralysis.

The autopsy was made immediately. There was clotted blood in the trachea and bronchi, and the lungs were congested. The stom-

achs appeared normal. There was some gas in the jejunum and ileum, and congestion in the posterior part of the ileum. The liver was pale and blotched, and the gall bladder was distended with gas. Tapeworms were present in the bile ducts and in the pancreatic duct. There were hemorrhagic spots on the surface of the thymus. The brain and spinal cord appeared normal.

The results of microscopic examination of the tissues are given on pages 7 to 10.

SYMPTOMS.

The most prominent symptom in all the cases of poisoning was a weakness of the hind quarters of the animals, which resulted in a staggering gait. There was in most of the cases depression and in

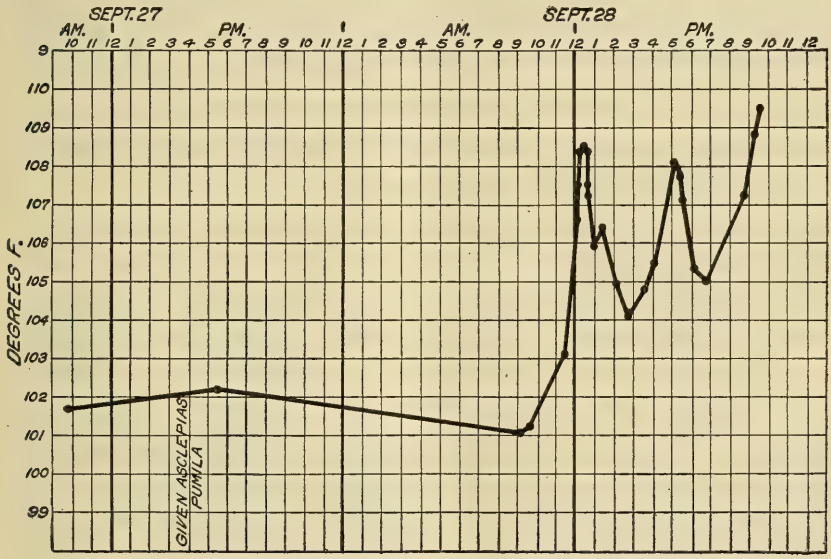

FIG. 2.—Temperature curve of Sheep 547.

some evident trembling, but the staggering was universally present and was particularly noticeable. This was not due in most cases to extreme weakness, for the animals could get about quite readily, but appeared in a gait which reminded one very much of a drunken man. This symptom of staggering was one which in some cases continued for several days. The pulse generally was weak and rapid, and the animals which were quite sick frequently accompanied the expirations with a grunt or a groan. In the cases which recovered there was no bloating, salivation, or spasm. It was quite noticeable in many of the cases that the animals when standing held the head high and the nose extended forward in a very characteristic fashion. In the animals which were fatally poisoned, in addition to the symptoms already described, there was some bloating and salivation, and

they exhibited violent spasms, accompanied with running movements. The temperature in the two fatal cases, Sheep 519 and 547, ran for a period very high, reaching a maximum of 107° F. in Sheep 519 and 109.6° F. in Sheep 547. In the spasms the latter animal threw itself at times in the opisthotonic position, and occasionally drew its head toward the thorax with a spasmodic motion.

In comparing these symptoms with those shown by *Asclepias galioides* there is nearly a complete resemblance. The symptoms exhibited in the fatal case of one could not be distinguished from those seen in the other. In the cases of intoxication with recovery, no spasms appeared, and in this respect *A. pumila* differs from *A. galioides*. This, however, may be explained by the fact that *A. pumila* is much less toxic than *A. galioides*, and it may be supposed that in the cases of intoxication there was not enough of the poisonous principle to produce the spasmodic stage.

TIME REQUIRED TO PRODUCE SYMPTOMS.

The following table shows the time that elapsed after the feeding of *A. pumila* before symptoms appeared:

TABLE 2.—*Time elapsed after feeding A. pumila before appearance of symptoms.*

Animal.	Quantity fed per 100 pounds of animal.	Result.	Time elapsed before symptoms appeared.		Animal.	Quantity fed per 100 pounds of animal.	Result.	Time elapsed before symptoms appeared.	
	Pounds.		*Hrs.*	*Mins.*		*Pounds.*		*Hrs.*	*Mins.*
Sheep 546	0.787	Sick	13	40	Sheep 546	1.339	Sick	13	40
Sheep 482	.787	do	30	15	Sheep 512	1.496	do	13	10
Sheep 486	.827	do	12	37	Sheep 520	1.693	do	13	46
Sheep 536	.866	do	16	50	Sheep 539	0.787	do	15	50
Sheep 539	.905	do	16	—	Sheep 516	1.85	do	17	40
Sheep 552	.984	do	15	45	Sheep 542	1.968	do	13	8
Sheep 516	.984	do	21	—	Sheep 519	2.165	Died	20	20
Sheep 547	1.063	do	13	8	Sheep 547	2.559	do	15	50
Sheep 554	1.181	do	14	13					

The average time of all cases shown in the table was 16 hours 17 minutes.

CONTINUATION OF SYMPTOMS.

It was noticed in the experimental cases of poisoning with *A. pumila* that the symptoms in some cases continued for a long period of time. The following table shows these facts. This table was prepared by taking the time between the appearance of symptoms and the last time when symptoms were noted. The actual periods were probably somewhat greater than those in the table, for in most cases the first symptoms were noted in the morning, and the animals may have been sick earlier. It is probable, too, that the symptoms extended somewhat beyond the time the table would indicate.

TABLE 3.—*A. pumila—Duration of sickness in cases of recovery.*

Designation of animal.	Duration of symptoms.	Designation of animal.	Duration of symptoms.
Sheep 546	1 day.	Sheep 554	2 days 8 hours.
Sheep 482	1 day.	Sheep 546	3 days 9½ hours.
Sheep 486	2 days 2½ hours.	Sheep 512	2 days 4½ hours.
Sheep 536	2 days 4 hours.	Sheep 520	1 day.
Sheep 539	7½ hours.	Sheep 539	1 day 8 hours.
Sheep 552	1 day 1 hour.	Sheep 516	4 days.
Sheep 516	1 day 17 hours.	Sheep 542	5 days.
Sheep 547	2 days 4½ hours.		

It will be noticed that the symptoms continued from a minimum of 7½ hours to a maximum of 5 days. With the exception of Sheep 539 the dosage was gradually increased in the order of the table. While there was no exact relation between the size of the dose and the duration of the symptoms, in a very general way the greater doses caused the more prolonged symptoms.

Of the two animals that died, death followed in Sheep 519 in 32 hours, and in Sheep 547 in 38 hours.

AUTOPSIES.

The findings from the post-mortem examinations of the two cases that terminated in death were not very positive. In each case the animal was bloated and there was some gas in the alimentary canal. However, so far as appeared without microscopic examination, there were no clearly marked lesions in any of the organs.

MICROSCOPIC CHANGES IN TISSUES OF SHEEP KILLED BY "ASCLEPIAS PUMILA."

Liver.—The hepatic cells in the two fatal cases were swollen so as to crowd the blood largely out of the capillaries. Cloudy swelling was pronounced in the liver of Sheep 547, the cytoplasm of the hepatic cells being very granular and having a ground-glass appearance, which made it difficult to make out fine details. This condition was not so well advanced in Sheep 519. The blood in many veins contained much hemosiderin pigment, areas of granular material, pieces of degenerated hepatic cells, and sometimes portions of epithelium from the walls of the veins. Some of the veins were engorged, others not. The bile ducts were often catarrhal. The changes in the hepatic cells in both animals, especially in Sheep 547, were more pronounced than in the *A. galioides* cases.

Kidneys.—The changes were practically like those found in the *A. galioides* cases, consisting of areas of congestion and edema and a swollen and somewhat degenerated condition of the epithelium, particularly in the convoluted tubules. In many tubules the lumina were practically filled by the swollen cells. Other cells were degenerated and partly disintegrated. Most nuclei stained well; a few stained

very faintly, while others were wrinkled. In the congested areas there were deposits of hemosiderin pigment, much of it being in tubule epithelial cells. Apparently pronounced hemolysis occurred.

Heart.—This tissue was mildly congested in some areas in Sheep 547, and a few minute hemorrhages occurred. In both animals the cross-striated appearance was less pronounced than usual, especially in areas where the cytoplasm was more granular than normal. This was less marked than that found in some of the *A. galioides* cases, but was not materially different and probably was the result of excessive activity of the cardiac muscle.

Lungs.—The sections of the lungs of Sheep 547 showed congestion; those of Sheep 519 did not. In both cases, however, hemosiderin pigment was present and thrombi were found in the arteries. While these thrombi differed somewhat in detail their origin may have been and probably was the same. The fact that they were found in arteries indicates that they were embolic in nature and possibly originated in the liver.

Thyroid.—The thyroid from each animal appeared to be normal except for a possible slight increase in connective tissue in Sheep 540, which had no connection with the *A. pumila* poisoning. In the *A. galioides* cases the thyroid tissue was congested.

Thymus.—The thymus from Sheep 547 was the only one examined. It was severely congested and was hemorrhagic as well as edematous. The medullary portion of the lobules was especially full of blood. No changes of importance were noted in the lymphoid cells, though in places large cells with finely granular cytoplasm, apparently phagocytic in nature, were present.

Nervous system.—The pronounced congestion noted in various parts of the nervous system in the *A. galioides* cases was absent in both the sheep poisoned by *A. pumila*, though all portions examined were somewhat edematous. In the lumbar cord of each case, and in the cerebrum and the cerebellum of Sheep 519, a small amount of diapedesis of erythrocytes had occurred. The nerve cells of the medulla and spinal cord and the Purkinje cells of the cerebellum in both cases had undergone marked changes. The Purkinje cells of sheep poisoned with *A. galioides* were found to show marked, or in some cases, extreme fatigue effects. Changes in other nerve cells were apparently fatigue effects.

Thrombi were found in the meninges and sometimes in the nervous tissue. Some of these contained fibrin, others appeared hyalin.

Alimentary canal.—The only portion showing changes which may be considered due to the *A. pumila* was in the ileum and suggested the presence of an irritant. The ileum of Sheep 547 was mildly congested, and hemorrhages had occurred. In the mucosa was an abnormal number of mononuclear leucocytes. A similar invasion, but

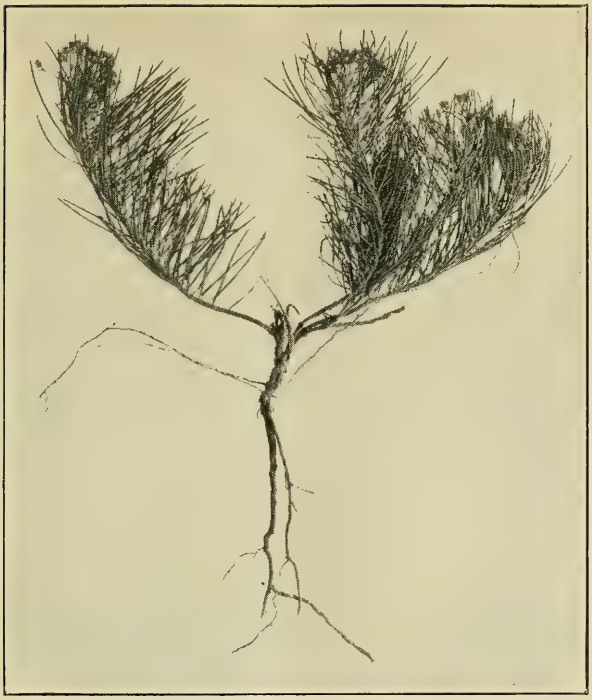

FIG. 1.—ASCLEPIAS PUMILA.

FIG. 2.—ASCLEPIAS PUMILA, SHOWING PLANTS GROWING FROM ADVENTITIOUS BUDS ON THE HORIZONTAL ROOT.

FIG. 1.—SHEEP 547, AT 10.46 P. M., SEPTEMBER 28.

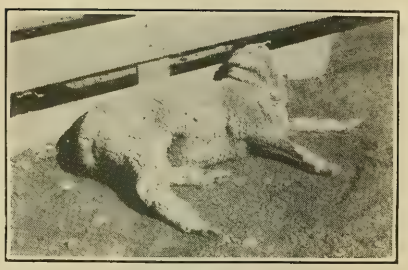

FIG. 2.—SHEEP 547, AT 11.36 A. M., SEPTEMBER 28.

FIG. 3.—SHEEP 547, AT 11.39 A. M., SEPTEMBER 28.

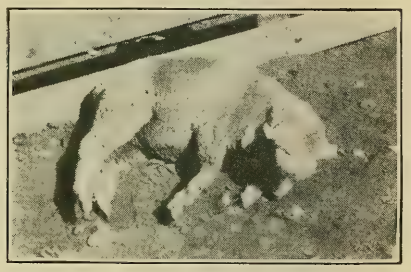

FIG. 4.—SHEEP 547, AT 11.43 A. M., SEPTEMBER 28.

FIG. 5.—SHEEP 547, AT 11.51 A. M., SEPTEMBER 28.

FIG. 6.—SHEEP 547, AT 11.55 A. M., SEPTEMBER 28.

FIG. 1.—SHEEP 547, AT 12.03 P. M., SEPTEMBER 28.

FIG. 2.—SHEEP 547, AT 12.06 P. M., SEPTEMBER 28.

FIG. 3.—SHEEP 547, AT 12.09 P. M., SEPTEMBER 28.

FIG. 4.—SHEEP 547, AT 1.01 P. M., SEPTEMBER 28.

FIG. 5.—SHEEP 547, AT 1.09 P. M., SEPTEMBER 28.

FIG. 6.—SHEEP 547, AT 1.45 P. M., SEPTEMBER 28.

of polymorphonuclear leucocytes, occurred in the mucosa of the ileum of Sheep 519. In some blood vessels thrombuslike areas occurred.

Spleen.—This organ was not very abnormal, though the presence of considerable hemosiderin pigment indicated a possible congestion which had subsided. The edematous condition of the Malpighian corpuscles in the spleen of Sheep 547 indicated a possible congestion.

While there was a marked similarity in the tissue changes to those in animals poisoned by *A. galioides*, there were certain slight differences, mainly of degree. On the whole the findings in the two sheep examined agreed very well.

TOXIC AND LETHAL DOSAGE.

The following table shows the dosage, estimated as green plant, of *A. pumila*, which resulted in sickness or death of the sheep.

TABLE 4.—*Dosages of A. pumila resulting in sickness or death.*

Animal.	Quantity per 100 pounds of animal.	Result.	Animal.	Quantity per 100 pounds of animal.	Result.	Animal.	Quantity per 100 pounds of animal.	Result.
	Pounds.			*Pounds.*			*Pounds.*	
Sheep 546...	0.787	Sick.	Sheep 516...	0.984	Sick.	Sheep 539...	0.787	Sick.
Sheep 482...	.787	Do.	Sheep 547...	1.063	Do.	Sheep 516...	1.85	Do.
Sheep 486...	.827	Do.	Sheep 554...	1.181	Do.	Sheep 542...	1.968	Do.
Sheep 536...	.866	Do.	Sheep 546...	1.339	Do.	Sheep 519...	2.165	Died.
Sheep 539...	.905	Do.	Sheep 512...	1.496	Do.	Sheep 547...	2.559	Do.
Sheep 552...	.984	Do.	Sheep 520...	1.693	Do.			

It will be noticed that the smallest quantity which produced intoxication was 0.787 pound per 100 pounds of animal. As shown in Table 1, the largest quantity fed without effect was 0.866 pound, to Sheep 530. In this case, however, there were possible symptoms. The smallest dose that produced death was 2.165 pounds per 100 pounds of animal. It may be recalled that in all the *A. pumila* cases the whole plant was used. There are no data to determine the comparative toxicity of different parts of the plant.

With *A. galioides* the smallest quantity of the whole plant that produced symptoms was 0.22 pound, and this dosage resulted in death. In comparing the two plants it is evident that *A. galioides* is nearly 3.6 times as toxic as *A. pumila.*

While, in the experiments with *A. galioides*, there was practically no difference between the toxic and lethal doses, in *A. pumila* it required nearly three times the toxic dose to produce death. As compared with *A. galioides* the lethal dose of *A. pumila* was 9.84 times as great. Because of the small number of cases which were compared, these figures must not be considered as exact, but they give a general idea of the relative toxicity of the two plants.

EXPERIMENTAL WORK WITH A. VERTICILLATA VAR. GEYERI.

A. verticillata, the whorled milkweed of the eastern part of the United States, is distributed throughout the Atlantic Plains and the Mississippi Valley. It differs materially from *A. galioides*, *A. pumila*, and *A. mexicana* in that it has long, fibrous roots and smooth pods.

A. verticillata var. *geyeri* can be distinguished from the typical form by its numerous adventitious buds on the fibrous roots. These slender, fibrous budded roots are often long and horizontal and thus simulate the single strong horizontal roots of *A. galioides*, *A. pumila*, and *A. mexicana*.

The material used in these experiments was collected at Missouri Valley, Iowa, on June 29, 1919.

Thirteen feedings of this plant were made to sheep by the balling gun, resulting in two animals becoming sick and one other very sick. Three feedings with hay were made to a horse, with no result.

The following table summarizes the experiments:

TABLE 5.—*Summary of feeding experiments with Asclepias verticillata var. geyeri (collected at Missouri Valley, Iowa, and air dried).*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Weight of plant (estimated as green plant) for 100 pounds of animal.	Remedy used.	Result.
Designation.	Weight.						
	Pounds.	1919.			*Pounds.*		
Sheep 523	82	July 14	Balling gun	Leaves and stems	0.140	None	Not sick.
Sheep 526	90.5	July 15	do	do	.184	do	Do.
Sheep 527	82	July 16	do	do	.276	do	Do.
Sheep 544	95.5	July 17	do	do	.368	do	Do.
Sheep 556	98.5	July 18	do	do	.735	do	Do.
Sheep 548	103	July 19	do	do	1.102	do	Do.
Sheep 540	97	July 20	do	do	1.470	do	Do.
Sheep 473	114.5	July 21	do	do	2.205	do	Very sick.
Sheep 556	106	Aug. 12	do	do	2.021	do	Not sick.
Sheep 546	89.25	Aug. 22	do	do	2.113	do	Do.
Sheep 552	97	Sept. 20	do	Leaves and stems with large proportion of stems.	2.168	do	Do.
Sheep 482	129	Sept. 23	do	Leaves	1.286	do	Sick.
Sheep 523	92	Sept. 25	do	do	1.470	do	Do.
Horse 126	995	July 15–16	Fed with hay.	Leaves and stems	.072	do	Not sick.
Horse 126	995	July 17	do	do	.15	do	Do.
Horse 126	995	July 18–21	do	do	.133	do	Do.

TYPICAL CASE OF SHEEP 473.

Sheep 473 was a wether weighing 114.5 pounds at the time of the experiment. On July 21, 1919, between 4.05 and 4.37 p. m., it received by the balling gun, per 100 pounds of animal, 2.205 pounds of the plant, estimated as green plant. At 6.40 a. m., July 22, the pulse was 152, weak, but regular, and the respiration was deep. It seemed weak in the hind legs and staggered as it walked.

At 7.23 a. m. it was down, throwing itself about spasmodically. The pupils were dilated and the animal was somewhat bloated. Opisthotonos was pronounced. The temperature at 6.40 a. m. was 101° F., and at 7.33 a. m. 103.4° F. At 8.02 a. m. running movements of the legs commenced. During most of the day and throughout the night following the condition of the animal did not change in any marked degree. It had mild spasms, accompanied by convulsive movements of the head and jaws. At times there was distinct trembling. Much of the time there was a good deal of bloat. Running movements occurred at times. The pulse was weak and the temperature at 2.10 p. m., and at 10.15 was as high as 105° F. The general condition was much like a mild case of *Asclepias galioides* poisoning. At no time were the spasms of a violent character; generally speaking, there was some correlation between the bloating and the spasmodic movements.

During the forenoon of July 23 it was more quiet than on the preceding day, but it still groaned, had a weak pulse, and at 9.35 a. m. the temperature was 104° F. At noon, while the pulse was still rapid, it was strong. During the afternoon the sheep drank water and became more quiet, though it was still bloated.

During the forenoon of July 24 the pulse varied, being weak at times, but on the whole showed improvement. The sheep attempted to eat at 9.35 a. m. It remained down until 2.30 p. m., when it got on its feet.

On July 25, while still much depressed, the sheep was improving steadily and both ate and drank. The temperature was normal, but the pulse, while strong, was still rapid. By the night of July 26 the sheep's condition was normal. It was kept under observation on July 27, and was turned into pasture on July 28.

SYMPTOMS.

Of the three sheep poisoned by *Asclepias verticillata* var. *geyeri*, two, Sheep 482 and Sheep 523, were sick, and one, Sheep 473, was very sick. Both Sheep 482 and Sheep 523 staggered and showed general weakness, which, in the case of Sheep 482, was more pronounced in the hind legs. In this animal the respiration was labored and in Sheep 523 a weak pulse was noted.

In the case of Sheep 473 all the typical symptoms of *Asclepias galioides* were noted, including weakness, especially marked in the hind legs, staggering, weak and rapid pulse, labored respiration (the expirations accompanied with groans), dilated pupils, elevated temperature, bloating, spasms with opisthotonos, and running movements. Spasmodic movements of the mandibles in a chewing movement were very noticeable.

TIME REQUIRED TO PRODUCE SYMPTOMS.

The following table shows the time that elapsed between the giving of the plant and the appearance of symptoms:

TABLE 6.—*Time elapsed after feeding A. verticillata var. geyeri before appearance of symptoms.*

Animal.	Quantity fed per 100 pounds of animal.	Result.	Time elapsed before symptoms appeared.	
	Pounds.		*Hrs.*	*Mins*
Sheep 473	2.205	Very sick	14	10
Sheep 482	1.286	Sick	15	35
Sheep 523	1.47	....do	20	35

The average time before symptoms appeared was 16 hours 47 minutes. As noted on page 6, this time, in the case of *Asclepias pumila*, was 16 hours and 17 minutes. In Bulletin 800, United States Department of Agriculture, page 34, it was shown that in the *Asclepias galioides* cases the average elapsed time was 14.1 hours. It is evident that in respect to the time elapsing between the feeding and the development of symptoms, the three species are practically alike.

CONTINUATION OF SYMPTOMS.

As in *A. pumila* cases, the symptoms persisted for a considerable length of time after their first appearance.

In Sheep 473, symptoms continued 4 days.
In Sheep 482, symptoms continued 2 days.
In Sheep 523, symptoms continued 1 day.

Sheep 473 was the only animal seriously affected, and the symptoms continued much longer than in the others.

COMPARISON OF DURATION OF SYMPTOMS IN A. PUMILA, A. VERTICILLATA VAR. GEYERI, AND A. GALIOIDES.

The following statement shows the time during which symptoms persisted in the *A. galioides* cases:

Horse 126, symptoms continued 6 days.
Cattle 750, symptoms continued 1⅓ days.
Sheep 478, symptoms continued 6 hours.
Sheep 506, symptoms continued 3 hours.
Sheep 534, symptoms continued 1 hour.
Sheep 542, symptoms continued 4 hours.
Sheep 372, symptoms continued 11 hours.
Sheep 522, symptoms continued (September 11) 3½ hours.
Sheep 522, symptoms continued (September 22) 4 hours.

For comparative purposes the horse and cow may be disregarded. In fact, the horse never completely recovered, although the immediate symptoms of the sickness disappeared.

Of the sheep, 534 was only slightly sick, and 372 and 522, in both experiments, showed only symptoms. The average time of the sheep cases was between 4½ and 4¾ hours, with a minimum of 1 hour and a maximum of 11 hours. The symptoms persisted longer in the more pronounced cases.

It was shown on page 7 that the *A. pumila* cases continued from 7½ hours to 5 days, and on page 7 that *A. verticillata* var. *geyeri* cases varied from 1 to 4 days, averaging 2 days and 8 hours.

If sheep poisoned by *A. galioides* recovered they were sick only a few hours, while with both *A. pumila* and *A. verticillata* var. *geyeri* the symptoms continued for a prolonged period.

Inasmuch as in all the whorled-milkweed cases the symptoms continued longer in the more pronounced cases, and as *A. galioides* is vastly the most toxic of the three species, one would expect the *A. galioides* cases to continue the longest. This unexpected result is a matter of a good deal of interest, and there is reason to think that it will be explained by the detailed chemical study of these plants, which is now in progress.

TOXIC DOSE.

The leaves and stems of the plant (*A. verticillata* var. *geyeri*) were given by the balling gun to 10 sheep. As *Asclepias galioides* had been found to be extremely toxic, the experiments were commenced with small doses, which were gradually increased until results were obtained. No effect was produced until Sheep 473 became very sick on 2.205 pounds per hundredweight of animal. As Sheep 556 was not affected by 2.021 pounds, nor Sheep 546 by 2.113 pounds, it is a fair inference that 2.205 pounds is very close to the toxic dose. The smallest toxic dose of *Asclepias galioides* is 0.22 pound, while the smallest toxic dose of *Asclepias pumila* is 0.787 pound. *Asclepias verticillata* var. *geyeri*, then, is about one-third as toxic as *A. pumila* and about one-tenth as toxic as *A. galioides* when leaves and stems are fed.

In feeding the leaves of the plant by the balling gun the smallest dose was 1.286 pounds. The smallest toxic dose of *A. galioides* leaves fed in the same way was 0.138 pound, so that in this case the *A. galioides* was about nine times as toxic as the *A. verticillata* var. *geyeri*.

COMPARATIVE TOXICITY OF STEMS AND LEAVES.

It may be noted that, as shown in the preceding paragraph, when leaves and stems are fed together the toxic dose is 2.2 pounds, while with leaves alone it is 1.378 pounds. This difference, of course, is due to the greater toxicity of the leaves. This is a matter of a great deal of interest, for extended experiments on *A. galioides* carried on since the publication of Bulletin 800 have conclusively shown a

similar relation in this plant. It follows that the losses by the whorled milkweeds are for the most part caused by eating the leaves rather than the stems.

SUMMARY.

Closely allied to the extremely poisonous whorled milkweed *Asclepias galioides* are two species, *A. pumila*, growing in the plains region east of the Rocky Mountains, and *A. verticillata* var. *geyeri*, growing in the eastern United States.

These two species produce in animals symptoms and pathological results closely resembling those produced by *A. galioides*.

As compared with *A. galioides*, *A. pumila* is about one-third as toxic and the Missouri Valley species (*A. verticillata* var. *geyeri*) about one-tenth as toxic.

As stock-poisoning plants these last two species have no history, but there is reason to think that if grazing animals were closely confined to them injurious results would follow.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 943

Contribution from the Office of Farm Management and Farm Economics

H. C. TAYLOR, Chief

Washington, D. C. ▼ April 30, 1921

COST OF PRODUCING WHEAT.

By M. R. Cooper and R. S. Washburn, *Assistant Farm Economists.*

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A PROBLEM OFTEN MISUNDERSTOOD.

"Cost of production" is a term which has been much used in recent years, often, it is believed, without a full comprehension of its significance. Some who had at first assumed that there was such a thing as one definite and specific cost figure for each of the staple farm products have become somewhat confused upon learning of the wide range of costs on different farms, and may have come even to doubt the utility of cost studies. It is rather difficult to arrive at a figure which properly represents the cost of producing wheat, or any other product, even on a given farm; furthermore, it is no simple matter to interpret properly the results. Because a task is difficult, however, is no reason for giving it up when the end in view is so important as in this case.

Note.—Acknowledgment is due to Messrs. M. A. Crosby and G. H. Miller, of the Office of Farm Management and Farm Economics, United States Department of Agriculture, for assistance in collecting the data which are presented in this bulletin. Acknowledgment is also due Miss Catherine R. Hawley, of the Office of Farm Management and Farm Economics, for excellent work in supervising the tabulation of the data which are used as a basis for this discussion. Thanks are extended to the numerous farmers who so willingly furnished information with reference to the cost of wheat production; also to the county agents and business men of the respective districts who so cordially assisted the enumerators in their work.

When it was shown that cost studies invariably bring out a wide range of costs instead of a single definite cost figure, the average was suggested as the representative cost figure, and often so used. Continued studies of the cost of producing farm products have indicated, however, that the average does not serve the purpose. It has been found that if prices merely equaled the average cost there would result anything but an inspiring standard, since the average usually tends to divide the producers into two groups of about equal size, one of which is producing at a cost above the average and the other at a cost below the average.

To be of any great significance, cost figures must be presented in terms of the ranges that exist in the final cost per unit of product and in the various elements of cost. The variations in the cost per unit of product in any representative farming area are so marked that they should be considered in any use of cost figures.

The Office of Farm Management and Farm Economics aims to present cost figures so that a complete picture of the range of individual costs can be obtained at a glance. From the presentation of the range of costs of farm products, it would appear that usually from 40 to 50 per cent of the production is at costs above the average. For this reason it is believed that, in order to stimulate adequate production through a period of years, the price at which the crop is sold will need to be appreciably above the average cost. It follows that the cost that will cover the "bulk" of the production of a given product is the figure that approximates what the price should be to maintain the industry. This consideration has led to the development of the "bulk-line" theory, which has recently assumed an important place in the discussion of the relation of production costs to price. The "bulk-line" theory is a modification and an attempt at practical application of the "marginal cost" or "greatest cost" theory of the relation of cost and price. In practice, the "bulk line" has sometimes been drawn to include 85 per cent of the production, but this is merely a tentative and more or less arbitrary figure. In reality the position of the "bulk line" varies with different commodities and from time to time, according to the alertness with which farmers adjust their production to market conditions. The "bulk-line" cost corresponds to the long-time average price which is essential, one year with another, to stimulate the production of that quantity of product which the market demands. What this "bulk-line" cost will be depends upon a number of factors, including the rate the farmer must pay for land, labor, and capital, and the standard of living which farmers, as a class, insist upon if they are to remain on the farm.

APPLICATION OF COST DATA TO FARM ORGANIZATION.

The farmer is primarily interested in the total net profit from his farm as a unit. The determination of the best possible combination of enterprises that provides the proper balance in the use of land, labor, and capital is a constant problem with him. Complete cost studies aid in analyzing seasonal demands for labor and capital and provide basic data of great value in planning farm reorganization.

The wide range in the costs computed for the wheat farms covered in this study suggests that considerable variation must have existed in the profits from producing wheat. It is not an easy matter to overcome the handicap that may be imposed by unfavorable weather or by certain diseases, or, perchance, by insect enemies. These are risks that demand the constant attention of the grower. Partly because of these risks, the progressive wheat farmer is intensely interested in the development of methods which will reduce his costs per unit of product and increase his profits.

A study of production costs on several farms will provide many suggestions with respect to practices that are more economical than the customary methods on the majority of farms in the community. Detailed analysis brings striking illustrations into the foreground. When a better plan or a more economical practice is displayed, farmers in general will appropriate the idea and will profit thereby.

SUMMARY OF RESULTS.

(197 spring-wheat records, 284 winter-wheat records.)

Cost per acre:

Spring wheat, $12.98 to $47.84; average, $22.40.

Winter wheat, $10.55 to $50.23; average, $27.80.

Cost per bushel:

Spring wheat, $1.15 to $14.38; average, $2.65.

Winter wheat, $0.96 to $8.24; average, $1.87.

Yield:

Spring wheat, 20.8 bushels per acre to less than 1 bushel; average, 8.4.

Winter wheat, 30 bushels per acre to 2.2; average, 14.9.

In the spring-wheat area about 33 per cent of the production was on the farms having costs above the average; in the winter-wheat area about 40 per cent of the production was on farms having costs above the average.

Costs not only differ on different farms during the same crop season, but they also exhibit a considerable range on any individual farm from year to year. The variations on the same farm from year to year may be due in part to weather conditions or other crop risks, or they may reflect the management of the operator. Even the most successful wheat grower may have an "off year" in wheat production, when the enterprise must be counted as a loss. Such a man would not suffer such losses annually for several years in succession without considering a change to a more profitable enterprise. There are men, however, who do continue in the business and who do sustain losses from year to year in growing wheat. Others just beginning farming may sustain losses in their initial crop seasons.

Thus in any year a considerable percentage of the producers of a given crop have costs which are above the price which is essential to stimulate adequate production through a series of years. Obviously the growers who habitually sustain losses must improve their methods, introduce more profitable enterprises, or take up other lines of business in which they may prove more efficient.

BASIC FACTORS AND COST ESTIMATES.

The basic acre-cost factors, such as hours of man and horse labor, amounts of manure and fertilizer applied, and quantities of seed and twine used, constitute much better measures of cost than the relatively unstable dollar. If these factors are known, labor rates and prices of materials can be applied for any given time, with the result that a close approximation of the total cost per acre can be obtained, which in turn will make possible a close estimate of the bushel cost when the yield per acre is known.

Where a solid foundation of such basic material is accumulated, it should provide a basis for the estimating of approximate acre and bushel costs for various products at the end of each crop year, so soon as the yield is known and before the crop is marketed. Thus, with the progress of the work in this field of investigation and as the detailed figures for a series of years are tabulated, the basic cost factors become increasingly valuable, because they serve as the basis of timely estimates which can not be made with any satisfactory degree of accuracy without them.

METHOD, SCOPE, AND PURPOSE OF PRESENT STUDY.

The purpose of this bulletin is to give the farmers of the western and northern plains, and others interested, as nearly as possible a complete statement of the facts concerning cost of wheat production for the season of the survey. With this in view, the data have been tabulated and presented in the following pages to show the

average cost and the variation in cost on individual farms and groups of farms in each area visited, and to indicate the more important reasons for the great variations in cost per acre and per bushel on individual farms.

The cost data were obtained from wheat growers to whom personal visits were made. Each record represents the experience of an individual farmer, the object being to learn for each farm visited, the detailed facts of production relative to all wheat land operated by the farmer during the crop year 1919.

This study is based on 481 farm records, of which 197 were obtained in five representative counties of the principal spring-wheat States, and 284 in nine counties in the leading winter-wheat States. Table I shows the districts visited and the total harvested acreage and total production on the farms visited in each district:

TABLE I.—*Distribution of cost records, spring and winter wheat, 1919.*

State and county.	Designation of area.	Number of records.	Acres harvested.	Bushels produced.
North Dakota:				
Grand Forks County	Larimore-Gilby	39	10,060	98,335
Morton County	New Salem-Hebron	39	5,840	25,835
South Dakota:				
Spink County	Redfield	39	9,500	93,862
Minnesota:				
Clay County	Moorhead	38	10,376	84,325
Traverse County	Wheaton-Graceville	42	7,071	59,690
Total spring wheat		197	42,847	362,047
Kansas:				
Ford County	Dodge City	32	9,817	130,890
Pawnee County	Larned	32	9,092	126,838
McPherson County	McPherson	35	4,652	59,034
Missouri:				
Saline County	Marshall	29	2,362	38,422
Jasper County	Carthage	30	2,949	56,730
St. Charles Co.	St. Charles	38	3,035	59,520
Nebraska:				
Phelps County	Holdredge	30	4,404	47,744
Saline County	Crete-Dorchester	35	2,008	36,334
Keith County	Ogallala	23	4,395	79,612
Total winter wheat		284	42,714	635,124

According to the Yearbook of the United States Department of Agriculture for 1919, farmers in the United States harvested 49,905,000 acres of winter wheat, yielding 731,636,000 bushels, and 23,338,000 acres of spring wheat, yielding 209,351,000 bushels.

In this survey a total area of 43,940 acres seeded to winter wheat, yielding 635,124 bushels, and a total area of 44,218 acres seeded to spring wheat, with a total production of 362,047 bushels, were used as the basis for computing costs. About equal acreages are shown for the spring and winter wheat groups, though in 1919 the winter-wheat acreage in the United States as a whole was a little more than twice as large as the spring wheat acreage.

GEOGRAPHY OF PRODUCTION.

The geographical distribution of the 1919 wheat acreage of the United States is shown by the accompanying map (fig. 1). Figure 2 shows the counties visited in each of the spring and winter wheat States in the course of this study.

The northern boundary of the Cotton Belt more or less closely coincides with the southern boundary of the Winter Wheat Belt. Likewise the northern boundary of the Winter Wheat Belt coincides with the southern boundary of the Spring Wheat Belt. Table II shows the acreage and production of spring and winter wheat in the States where records were obtained, as compared with the total production in the United States. Of the spring-wheat area in 1919 about 66 per cent was in the States of Minnesota, North Dakota, and South Dakota. Of the winter-wheat area in 1919, over 39 per cent was in the States of Kansas, Missouri, and Nebraska.

TABLE II.—*Importance of 1919 wheat acreage and production in States where records were obtained.*

Region.	Acreage.	Per cent of total acreage (U. S.).	Production.	Per cent of total production (U. S.)
SPRING WHEAT.			*Bushels.*	
North Dakota	7,770,000	33.3	53,613,000	25.6
South Dakota	3,650,000	15.7	29,200,000	14.0
Minnesota	3,950,000	16.9	36,735,000	17.5
Total	15,377,000	65.9	119,548,000	57.1
WINTER WHEAT.				
Kansas	11,594,000	23.2	150,722,000	20.6
Missouri	4,274,000	8.6	57,699,000	7.9
Nebraska	3,716,000	7.4	54,997,000	7.5
Total	19,584,000	39.2	263,418,000	36.0

During the last 70 years the center of wheat production in the United States has moved constantly from east to west. Seventy years ago New York was one of the great wheat-producing States. From New York the region of heaviest production has moved westward, through Ohio, southern Wisconsin, and northern Illinois, until now the center of production for winter wheat is in central Kansas and for spring wheat in North Dakota. In 1919 Kansas produced 16 per cent and North Dakota 5.7 per cent of all wheat grown in the United States.

The agricultural development of these western and northern plains has been largely responsible for the wheat production having kept pace with our wheat consumption. Wheat is not grown to any extent in the South, because of the warm, humid climate, which results in injury from fungus diseases, and also because of the competition with the cotton crop.

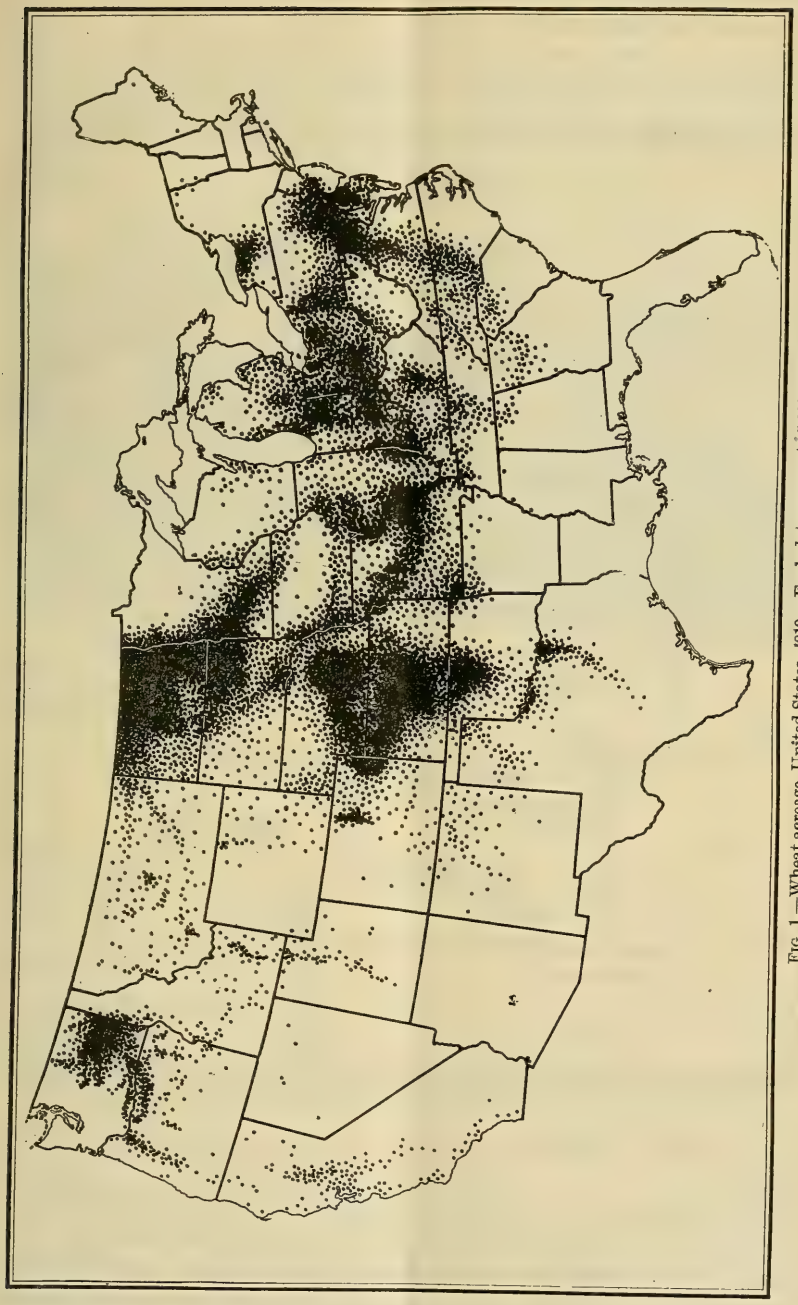


FIG. 1.—Wheat acreage, United States, 1919. Each dot represents 5,000 acres.

CROPS GROWN IN AREAS SURVEYED.

Table III shows the percentages of the total crop acreage devoted to the various crops grown in the regions of the survey. Of all the crops grown, wheat occupies first place. (See fig. 3.) The percentage of the total acreage devoted to wheat ranges from 39 per cent in

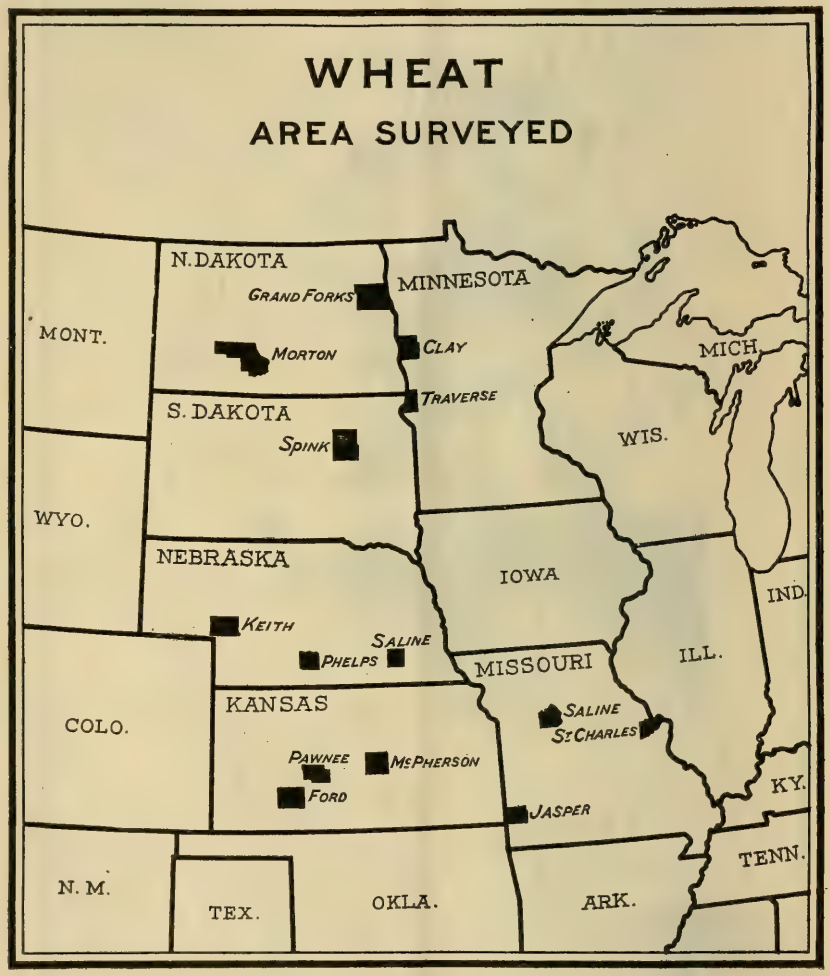


FIG. 2.—Black areas indicate the counties where wheat records were obtained.

Saline County, Nebraska, to about 80 per cent in Ford County, Kansas.

The percentage of total acreage devoted to wheat in Missouri and Nebraska was considerably lower than in some other districts visited because of the competition with corn in these States. In the spring-wheat districts, because of the smaller amount of rainfall and the shorter growing season, corn does not compete with wheat to so great an extent.

The oat acreage was fairly well distributed in all districts, with a slightly larger acreage per farm in the spring-wheat districts. This is to be expected, since oats require a cool climate. Barley was

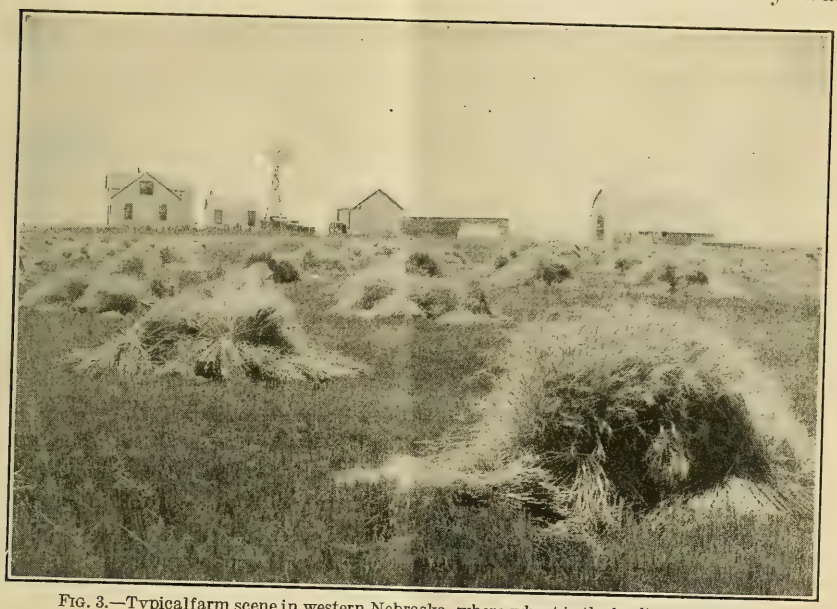


FIG. 3.—Typical farm scene in western Nebraska, where wheat is the leading farm crop.

found in all districts visited, except Missouri, but, like oats, was more generally grown in the spring-wheat districts.

TABLE III.—*Distribution of crop area, 1919 (481 farms).*

State and county.	Crop acres per farm.	Per cent of crop area in —									
		Wheat.	Corn.	Oats.	Barley.	Rye.	Hay and alfalfa.	Summer fallow.	Sorghum.	Flax.	Miscellaneous crops.
SPRING WHEAT AREAS.											
North Dakota:											
Grand Forks County	573.4	49.0	3.1	12.1	7.5	2.9	10.3	4.0	.....	3.4	7.7
Morton County	409.2	39.6	2.5	6.7	4.3	8.3	21.4	5.4	.....	4.2	7.6
South Dakota:											
Spink County	437.7	55.7	16.9	6.8	5.3	1.0	12.2	.....	.....	.....	2.1
Minnesota:											
Clay County	496.0	55.1	5.4	10.4	5.8	.7	8.1	3.4	.....	1.3	9.8
Traverse County	374.5	45.1	13.4	16.3	6.9	1.3	11.2	1.2	.....	2.4	2.2
WINTER WHEAT AREAS.											
Kansas:											
Ford County	398.7	79.7	3.8	5.1	1.9	.....	2.0	.....	6.1	.....	1.4
Pawnee County	384.2	75.5	8.4	.9	1.2	.9	3.5	.....	4.6	.....	5.0
McPherson County	204.8	69.6	10.6	4.3	.1	2.2	10.3	.....	1.6	.....	1.3
Missouri:											
Saline County	181.5	47.9	40.5	3.7	.....	.....	5.6	.....	.....	.....	2.3
Jasper County	155.4	63.5	16.2	14.0	.....	.....	2.8	.....	.....	.....	3.5
St. Charles County	130.1	61.4	25.9	4.6	.....	.....	7.0	.....	.....	.....	1.1
Nebraska:											
Phelps County	271.4	56.2	28.6	2.4	3.8	.8	5.2	.....	2.3	.....	.7
Saline County	149.9	38.7	32.8	11.0	2.0	.1	12.4	.....	.4	.....	2.6
Keith County	420.0	52.1	23.1	2.9	2.6	8.0	8.4	.....	1.1	.....	1.8

No summer-fallow land was found in the winter-wheat districts, and in the spring-wheat areas only a small percentage of the crop area was summer-fallowed.

The area devoted to flax production was also limited.

The miscellaneous crops consisted principally of potatoes, millet, spelt, and clover and timothy seed.

CLIMATE.

Although wheat is grown in localities in the United States having widely different climates, it is a cool-weather crop, and produces the largest yield of best quality where cool, moderately wet weather prevails during the growing season and dry, sunny weather during the ripening period. Wheat is not generally a safe crop where the mean annual precipitation is less than 15 inches. In the districts of densest production (North Dakota and Kansas) the annual precipitation ranges from 18 to 32 inches. Where the rainfall exceeds 45 inches a year wheat does not thrive, principally because rust and fungus diseases are more prevalent there than in less humid districts.

The distribution of the rainfall is as important as the total amount. For instance, in Ford County, Kans., in 1918, the total rainfall was normal, but the average yield of wheat for the county was only 3 bushels per acre. This low yield was due mainly to the small amount of rainfall during the months of April, May, and June; in June it was only one-fourth inch; and for the three months but 4.5 inches, as compared with a normal rainfall of about 8 inches for these months.

Table IV shows the average yearly precipitation for all districts visited, as compared with the total rainfall for the year 1919:

TABLE IV.—*Mean annual rainfall for districts visited.*

Region.	Weather station.	Annual average.		1919
SPRING WHEAT.				
North Dakota:			*Inches.*	*Inches.*
Grand Forks County	Larimore	From 1910 to 1918	20.20	25.32
Morton County	New Salem	From 1909 to 1918	17.87	13.68
South Dakota:				
Spink County	Melette	From 1892 to 1918	20.64	21.41
Minnesota:				
Clay County	Moorhead	From 1881 to 1918	23.65	23.75
Traverse County	Wheaton	From 1915 to 1918	18.47	21.18
WINTER WHEAT.				
Kansas:				
Ford County	Dodge City	From 1896 to 1918	20.32	13.70
Pawnee County	Larned	From 1860 to 1918	22.70	19.88
McPherson County	McPherson	From 1889 to 1918	31.16	31.46
Missouri:				
Saline County	Marshall	From 1890 to 1918	38.63	36.12
Jasper County	Joplin	From 1878 to 1914 [a]	41.26	
St. Charles County	St. Charles	From 1890 to 1918	36.68	35.11
Nebraska:				
Phelps County	Holdredge	From 1891 to 1918	24.84	25.83
Saline County	Crete	From 1880 to 1918	28.85	33.42
Keith County	Lodgepole	From 1890 to 1918	16.62	18.95

[a] No record taken after 1914.

Over a series of years approximately one-half of the annual precipitation in all districts occurred during the four months, April, May, June, and July. The lowest annual precipitation was recorded in Keith County, Nebr. (16.62 inches), and the highest in Jasper County, Mo. (41.26 inches).

In Ford County, Kans., and Morton County, N. Dak., the rainfall in 1919 was considerably below normal. In Ford County the distribution during the growing season was sufficient to insure a fairly good yield. However, in Morton County the rainfall was not well enough distributed to produce an average yield.

SOILS.

Wheat was grown in the regions visited on fairly deep limestone soils, generally well supplied with humus. The lime content was especially high in Ford County, Kans., Keith County, Nebr., and Morton County, N. Dak., where the amount of rainfall is limited and the soluble material has not been leached out. In general, little wheat was grown on sandy soils, since this soil type is not so well adapted to wheat growing because of its tendency to blow during high winds.

On these soils no commercial fertilizer was used except in the Missouri areas.

COMPARATIVE WHEAT YIELDS.

The yield of farm crops in any given region is influenced by a number of things, such as soil fertility, weather, insect and fungus diseases, crop management, etc. Therefore, the results of any attempt to tabulate yields for a single year must be considered as suggestive rather than definite and conclusive. Yet when yields are tabulated over a series of years an average yield can be arrived at which will be of value in measuring the possibilities of the area for a given crop grown in that region.

In Table V the average wheat yields for the State, county, and farms visited in 1919 are recorded. In some cases the figures on yield were obtained from the Bureau of Crop Estimates, United States Department of Agriculture; in others, from State boards of agriculture.

The average yield of spring wheat in the United States in 1919 was 9 bushels per acre, in contrast with a yield of 8.4 bushels per acre for the total spring wheat area surveyed. The average yield for all winter wheat in 1919 was 14.7 bushels per acre, while the average yield for the farms surveyed in this region was 14.9 bushels per acre.

The abnormally low yield of wheat in Morton County, N. Dak., was partially due to an insufficient amount of total rainfall which was not well distributed over the growing period.

In Grand Forks County, N. Dak., and in Clay and Traverse Counties, Minn., a period of moist, hot weather occurred just prior to harvest time, resulting in wheat rust, which reduced wheat yields appreciably in these counties.

It will be noted (Table V) that the largest number of farms in the spring-wheat districts are included in the group having a yield of from 5 to 10 bushels per acre, while the largest number in the winter wheat districts come within the group having a yield of from 15 to 20 bushels.

The average 1919 yield per acre for the farms included in this study was determined by dividing the total production by the total harvested acreage. The costs presented in this bulletin are based on the actual yields obtained on these farms.

TABLE V.—*Annual yields, spring and winter wheat.*

Region.	10-year State average.	9 or 10 year county average.	Average for farms visited, 1919.	Range in yield per acre.					
				Under 5 bush.	5 to 10 bush.	10 to 15 bush.	15 to 20 bush.	20 to 25 bush.	25 bush. and over.
SPRING WHEAT.				*No. of farms.*	*No. of farms.*	*No. of farms.*	*No. of farms.*	*No. of farms.*	*No of farms.*
North Dakota	10.6								
Grand Forks County		12.9	9 8	1	16	20	2		
Morton County		9.2	4.4	25	14				
South Dakota	11.3								
Spink County		10.8	9.9		24	13	2		
Minnesota	14.1								
Clay County		13.5	8.1	2	26	9	1		
Traverse County		11.8	8.4	1	32	9			
Total spring wheat				29	112	51	5		
Per cent of total				15	57	26	2		
WINTER WHEAT.									
Kansas	13.8								
Ford County		12.6	13.3	3	7	6	10	6	
Pawnee County		12.9	13.9	1	4	16	10	1	
McPherson County		14.7	12.7		8	17	10		
Missouri	14.3								
Saline County		15.7	16.3		3	7	12	7	
Jasper County		15.8	19.2				17	12	1
St. Charles County		15.2	19.6			2	12	22	2
Nebraska	16.0								
Phelps County		14.1	10.8		15	13	2		
Saline County		21.1	18.1			6	17	12	
Keith County		19.5	18.1		2	2	11	5	3
Total winter wheat				4	39	69	101	65	6
Per cent of total				1	14	24	36	23	2

REQUIREMENTS OF PRODUCTION.

In arriving at the cost of wheat production the following elements of cost have been considered:

Labor, which includes (1) all direct man and horse farm labor, and (2) contract labor, including such items as marketing wheat at a fixed charge per bushel and various labor operations in growing the wheat crop, where done at a contract rate per acre.

Materials, including seed wheat (with cost of treating seed); barnyard manure and straw, fertilizer and twine.

Thrashing, which includes (1) cash paid per bushel, (2) board for the part of thrashing crew furnished by the thrasherman, and (3) any thrashing fuel furnished by the farmer.

Use cost of land, or land rent, which includes (1) interest on wheat land investment for owned farms, (2) the market value of the share of wheat given at thrashing time to the landlord as rent, and (3) the actual cash paid for cash-rented wheat land.

Other costs, including (1) farm taxes and insurance; (2) special crop insurance, (3) use of tractor and other farm machinery; (4) loss due to abandoned wheat acreage; and (5) overhead.

Credits, including (1) straw, (2) pasture, and (3) insurance received for damages to the growing wheat crop.

SUMMARY OF COSTS, BY DISTRICTS.

In Tables VI and VII is presented a summary of average cost per acre and per bushel for the areas surveyed. This enables a comparison of the total costs of production by districts, and the part of the total costs that is chargeable to labor, materials, thrashing, use of land, and other costs.

TABLE VI.—*Summary of average cost per acre and per bushel of spring wheat, 1919 (197 farms).*

Item.	North Dakota.		South Dakota.	Minnesota.		All spring wheat.	Per cent of total cost.
	Grand Forks County.	Morton County.	Spink County.	Clay County.	Traverse County.		
Number of records	39	39	39	38	42	197	.....
Total acres	10,060	5,840	9,500	10,376	7,071	42,847	.....
Total production (bushels)	98,335	25,835	93,862	84,325	59,690	362,047	.....
Average yield per acre (bushels)	9.8	4.4	9.9	8.1	8.4	8.4	.....
Labor (land preparation and seeding)	.....	.....	.....	.....	.....	.....	18.0
Man labor cost per acre	$1.24	$1.69	$1.16	$1.29	$1.40	$1.32	.....
Horse labor cost	2.77	3.34	2.54	2.35	3.17	2.76	.....
Contract labor	.10	.....	.01	.01	.....	.03	.....
Labor (harvesting, marketing)	.....	.....	.....	.....	.....	.....	14.4
Man labor cost	1.29	2.20	2.00	2.26	2.72	2.04	.....
Horse labor cost	.88	1.18	1.02	1.36	1.58	1.18	.....
Contract labor	.01	.06	.06	.02	.03	.04	.....
Material costs	.....	.....	.....	.....	.....	.....	17.1
Seed and seed treatment	3.39	2.98	2.78	3.45	3.38	3.21	.....
Binder twine	.57	.02	.39	.50	.46	.42	.....
Manure and straw	.22	.29	.17	.40	.20	.26	.....
Thrashing	2.78	.43	2.68	1.18	1.13	1.78	7.8
Use cost of land	4.22	2.15	7.58	6.16	5.98	5.44	23.9
Other costs	.....	.....	.....	.....	.....	.....	18.8
Taxes and insurance	.29	.21	.32	.46	.42	.35	.....
Special crop insurance	.18	.21	.25	.54	.11	.28	.....
Use cost of tractor	.07	.19	.26	.67	.21	.30	.....
Use cost of other farm machinery	1.50	1.98	1.36	1.30	1.43	1.47	.....
Loss on abandoned acreage	.97	.94	.....	.....	.....	.36	.....
Overhead	1.59	1.46	1.31	1.54	1.69	1.51	.....
Total cost per acre	22.07	19.33	23.89	23.49	23.91	22.75	100.0
Credits	.19	.50	.19	.58	.30	.35	.....
Net cost per acre	21.88	18.83	23.70	22.91	23.61	22.40	.....
Net cost per bushel	2.24	4.26	2.40	2.82	2.80	2.65	.....
Without land rent:							
Net cost per acre	17.66	16.68	16.12	16.75	17.63	16.96	.....
Net cost per bushel	1.81	3.77	1.63	2.06	2.09	2.01	.....

TABLE VII.—*Summary of average cost per acre and per bushel of winter wheat, 1919 (284 farms).*

Item.	Kansas.			Missouri.			Nebraska.			All winter wheat.	Per cent of total cost.
	Ford County.	Pawnee County.	McPherson County.	Saline County.	Jasper County.	St. Chas. County.	Phelps County.	Saline County.	Keith County.		
Number of records	32	32	35	29	30	38	30	35	23	284	.....
Total acres	9,817	9,092	4,652	2,362	2,949	3,035	4,404	2,008	4,395	42,714	.....
Total production (bushels)	130,890	126,838	59,034	38,422	56,730	59,520	47,744	36,334	79,612	635,124	.....
Average yield per acre (bushels)	13.3	13.9	12.7	16.3	19.2	19.6	10.8	18.1	18.1	14.9	.....
Labor (land preparation and seeding)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.8
Man labor cost per acre	$0.93	$0.75	$1.62	$1.50	$2.21	$1.82	$1.25	$2.13	$0.83	$1.23	.....
Horse labor cost	2.74	1.85	3.58	3.08	4.30	3.70	2.46	4.29	.97	2.70	.....
Contract labor	.02	.....	.02	.11	.02	.....	.....	.01	.18	.03	.....
Labor (harvesting, marketing)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.6
Man labor cost	3.75	2.80	3.89	4.78	4.68	4.89	3.61	5.77	4.61	3.94	.....
Horse labor cost	2.20	1.38	1.61	1.83	2.22	1.96	1.67	2.53	1.28	1.79	.....
Contract labor	.02	.02	.....	.12	.20	.....	.....	.....	1.32	.16	.....
Material costs	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.4
Seed and seed treatment	1.79	2.19	2.36	2.73	2.52	2.58	2.13	2.99	1.72	2.18	.....
Binder twine	.31	.21	.63	.66	.53	.55	.63	.87	.44	.45	.....
Manure and straw	.06	.10	.39	.06	.44	.40	.16	.27	.02	.17	.....
Green manure	.....	.....	.....	.....	.....	.33	.....	.....	.....	.02	.....
Fertilizer	.....	.....	.....	.01	2.07	.01	.....	.....	.....	.14	.....
Grasshopper poison	.02	.....	.....	.....	.....	.....	.01	.....	.....	.01	.....
Thrashing	2.58	2.67	2.83	3.37	1.45	1.86	1.18	1.98	1.91	2.30	8.0
Use cost of land	6.14	7.77	8.44	13.92	10.30	11.28	6.94	13.25	9.57	8.59	30.0
Other costs	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.2
Taxes and insurance	.13	.18	.21	.43	.24	.36	.18	.63	.12	.22	.....
Special crop insurance	1.06	1.23	.27	.07	.10	.06	.63	.21	1.15	.74	.....
Use cost of tractor	.12	.26	.33	.20	.19	.47	.14	.37	1.39	.35	.....
Use cost of other farm machinery	1.15	1.32	1.98	1.51	1.77	2.13	1.23	1.93	1.68	1.51	.....
Loss on abandoned acreage	.24	.18	.69	.91	.06	.....	.32	.15	.....	.26	.....
Sack rent	.....	.....	.....	.07	.....	.07	.....	.....	.....	.01	.....
Overhead	1.75	1.44	2.03	2.19	2.48	2.17	1.57	2.50	1.59	1.81	.....
Total cost per acre	25.01	24.35	30.88	37.55	35.78	34.64	24.11	39.88	28.78	28.62	100.0
Credits	.71	1.29	.68	2.27	1.14	.51	.27	.34	.26	.82	.....
Net cost per acre	24.30	23.06	30.20	35.28	34.64	34.13	23.84	39.54	28.52	27.80	.....
Net cost per bushel	1.82	1.65	2.38	2.17	1.80	1.74	2.20	2.19	1.57	1.87	.....
Without land rent:											
Net cost per acre	18.16	15.29	21.76	21.36	24.34	22.85	16.90	26.29	18.95	19.21	.....
Net cost per bushel	1.36	1.10	1.71	1.31	1.26	1.17	1.56	1.45	1.05	1.29	.....

The gross costs are partially offset by credits for pasture and any straw utilized on the farm. The difference between the gross cost and the sum of these credits is the net cost of producing wheat. The cost per bushel was obtained by dividing the total net cost by the total yield. The average acre cost of each item of expense was computed on a weighted basis by dividing the total cost of each item by the total wheat acreage. This method results in a relatively low regional cost per acre for items of expense that did not occur on the entire acreage. As an illustration, the cost of binder twine in Morton County, N. Dak., where but 10 per cent of the acreage was cut with a binder, amounted to but 2 cents per acre when distributed over the total wheat acreage.

Again, in Keith County, Nebr., less than 1 per cent of the wheat acreage was manured at a prorated cost of 2 cents per acre. Such averages, of course, have no direct significance to the grower, though they may have weight in determining a regional cost.

An analysis of the total cost for spring and winter wheat under the five headings, "labor," "materials," "thrashing," "use cost of land," and "other costs," shows that labor constitutes about 32 to 35 per cent of the total cost of production; thrashing about 8 per cent; materials from 10 to 17 per cent; land rent from 24 to 30 per cent; and "other costs" from 17 to 19 per cent.

The two largest items of cost, "labor" and "land rent," constitute about 56 and 64 per cent, respectively, of the total costs in the spring and winter wheat areas. The variations in labor practices and costs are shown in detail elsewhere in this bulletin.

The average use cost of land in each district represents a combination of tenures and is not indicative of the rent charge for any particular renting practice. The land rent charge, therefore, is a composite figure, made up of the interest on land values on owned farms and the cash or share rent paid on rented farms. These variations in land values and variations in yields and in the acreage of wheat produced on owned and rented land are reflected in the differences in the average land rent charges for the various districts. Because of the lower land values and the lower yield of wheat in the Spring-Wheat Belt the charge for the use of land is considerably lower here than in the Winter-Wheat Belt.

Nearly 40 per cent of the spring wheat and 60 per cent of the winter wheat acreage in question was grown by renters. To these men the charge for the use of land is an important item of cost. To the operator who owns his land a charge for the use of land is less vital from the standpoint of actual cash outlay. The owner, however, has an investment in wheat land, which, if rented out, would return to him an income in cash or equivalent thereto in the form of a share of the wheat crop. Therefore, in determining the cost of producing wheat on owned land, interest on investment in land has been considered an item of cost in order that cost of production on owned and rented land may be comparable. The importance of the charge for use of land may be seen by referring to the last two items in Tables VI and VII, where the cost per acre and per bushel without land rent has been shown. In the case of spring wheat the charge for use of land amounted to 64 cents a bushel and in the case of winter wheat 58 cents a bushel.

In the winter wheat districts the three counties in Missouri had the most uniform cost per acre. With the exception of Saline County, Nebr., the average cost for the Missouri areas was considerably higher than the cost for the other winter-wheat areas. The

principal reasons for this are found in higher land values and a more thorough preparation of the land for wheat in the three Missouri districts and in the Saline County, Nebr., area.

Since yield has a much less important influence on the cost per acre than on the cost per bushel, the acre cost should be the unit used in comparing the cost of wheat production in the districts visited. The cost of twine, shocking, thrashing, and marketing vary somewhat with yield; but, unless the yields are abnormal, this variation is so slight that the costs per acre are comparable within a region. The yield per acre, however, as already pointed out, has a decided effect on cost per bushel, as will be seen from an examination of Tables VI and VII. The average cost of producing winter wheat was $27.80 per acre and $1.87 per bushel, as compared with an average cost for spring wheat of $22.40 per acre and $2.65 per bushel. It will be seen that the average cost per acre for all spring wheat was $5.40 less than for all winter wheat, though the average cost per bushel was $0.78 greater. This difference in cost per bushel is due to a lack of relation between the cost of producing an acre of wheat and yield obtained; the *cost* per acre of winter wheat being 24 per cent greater than for spring wheat, whereas the *yield* per acre was 77 per cent greater.

RANGE IN COST PER ACRE, BY COUNTIES.

In Table VIII the farms have been grouped according to cost per acre. In the five spring-wheat counties the acre cost per farm ranged from $12.98 to $47.84. Only 7 per cent of these farms, however, had a cost in excess of $30 per acre, and the number with a cost of less than $20 per acre was of small importance in all but the two counties visited in North Dakota. In the two North Dakota areas over 78 per cent of the farms had a cost of $25 or less per acre. In Grand Forks County comparatively low labor and rent costs were found on a goodly number of farms. In Morton County the labor costs were fairly high, which was partially offset by a low thrashing cost and exceptionally low rent costs.

The wide range in acre costs within each area is explained in the following manner: As a rule, those farms showing a cost of less than $20 per acre had comparatively low labor costs, combined with a low rent charge, the latter being due to a low valuation of land on owned farms and low yields on rented farms; and since the value of the share of wheat given to the landlord for the use of the land has been charged as rent to the operator, the rent charge on rented farms varied with the yield obtained. In this connection it should be noted that a good many of the farms in each area having a cost of less than $20 per acre were share-rented farms. Again, the farms in this cost group did not have excessive costs from abandoned wheat acreage.

The next two and important groups, $20 to $25 and $25 to $30 per acre, contained farms on which there was either a gradual or irregular increase in all or a part of the various items of cost over those farms in the preceding group. These increases were most pronounced in labor and rent costs, although a few farms came within these groups because of abandoned acreage costs.

TABLE VIII.—*Range in cost per acre, by counties, spring and winter wheat, 1919 (481 farms).*

District.	Number of records.	Cost per acre.					
		Under $20 (number of farms).	$20 to $25 (number of farms).	$25 to $30 (number of farms).	$30 to $35 (number of farms).	$35 to $40 (number of farms).	$40 and over (number of farms).
SPRING WHEAT.							
North Dakota:							
Grand Forks County	39	10	18	9	1	1	.....
Morton County	39	21	12	6	.....	.....	.....
South Dakota:							
Spink County	39	5	20	12	2	.....	.....
Minnesota:							
Clay County	38	6	17	9	6	.....	.....
Traverse County	42	4	21	14	2	.....	1
Total, spring wheat	197	46	88	50	11	1	1
Per cent of total	100	23	45	25	6	.5	.5
WINTER WHEAT.							
Kansas:							
Ford County	32	10	7	11	2	2	.....
Pawnee County	32	4	18	9	1	.....	.....
McPherson County	35	.....	7	12	11	3	2
Missouri:							
Saline County	29	.....	2	1	10	8	8
Jasper County	30	.....	.....	3	17	6	4
St. Charles County	38	.....	.....	5	16	11	6
Nebraska:							
Phelps County	30	5	15	9	1	.....	.....
Saline County	35	.....	.....	1	3	16	15
Keith County	23	3	3	8	4	3	2
Total, winter wheat	284	22	52	59	65	49	37
Per cent of total	100	8	18	21	23	17	13

The farms in the three highest cost groups had one or more excessive items of cost. Thus in the Grand Forks area the farm having a cost of $30 to $35 per acre was a rented farm with a yield of 12 bushels per acre based on the acres harvested, but about one-half of the acreage seeded was abandoned before harvest. In the same area the farm in the $35 to $40 class abandoned 150 out of 210 acres.

The two farms having the highest cost in Spink County came in the $30 to $35 group. One of these farms had a very high rent cost and the other a high labor and rent cost combined with a comparatively high cost for seed wheat.

The eight farms in Minnesota with costs of $30 to $35 per acre had high labor and rent costs, and the one farm in Traverse County with a cost of over $40 was a small farm highly capitalized. The

labor, rent, equipment, and overhead costs were comparatively high, with a resultant cost of $47.84 per acre.

In the winter-wheat areas the variation in cost per acre on farms in the same county was due primarily to the same causes that affected costs on the spring-wheat farms. Thus in Ford County three of the four farms having a cost of $30 to $40 per acre were share-rented farms on which good yields were obtained, making a high-rent charge to the operator. The one farm with a cost of $30 to $35 per acre in Pawnee County was a share-rented farm also with a high yield. Of McPherson County's five farms appearing in the two highest cost groups three had abandoned acreage and the other two were share-rented farms with good yields. The two farms with lowest acre costs in Saline County, Mo., had comparatively low-labor costs and exceptionally high credits for straw and pasture. The farms having a cost of $40 and over per acre in the three Missouri counties had no item of expense for abandoned acreage, but were universally high in labor costs, and in some instances had high thrashing and rent costs; the latter owing to high land values or very good yields of wheat. In the Nebraska areas the variation in cost per acre was attributable to the reasons mentioned above, the principal causes of variation closely following those mentioned for the Missouri areas.

In the three Missouri areas the prominence of the farms with comparatively high acre costs is due to thorough land preparation, good yields, and high land valuations. Likewise on the farms in Saline County, Nebr., which are relatively small, much labor is devoted to land preparation, good yields were obtained, causing a fairly high thrashing charge per acre, and land valuations were higher than in any other area visited except one.

Thus it is evident that the acre cost of growing wheat is in no way constant, but may vary as the quantities and values of the various items of cost vary. The amount and the cost of labor devoted to raising an acre of wheat may be influenced by many things, some of which the farmer can not control, and in consequence the acre cost may change from year to year. This is borne out by a study of individual farm costs in each area. The amount of labor devoted to seed-bed preparation was not uniform in any given locality. This lack of uniformity was due to different practices followed on individual farms and even on different fields on the same farm. Soil conditions, weather conditions, available labor, distance from market, etc., all have much to do with the hours devoted to raising an acre of wheat.

As an example of variation in practice it was not uncommon to find farmers in certain winter-wheat areas who plowed a part of the land, listed a part, and disk-drilled a part in cornstalk or grain stubble land without further preparation. In some instances a part of the

wheat land was in such condition as a result of heavy rains that an 8-foot binder was able to cut but one-third to one-half of a full swath. The influence of such conditions on labor requirements not only in cutting but in shocking such wheat is apparent The abandonment of a high percentage of the acreage has a decided effect on acre cost. Rent or interest on land, the value of which ranged from $30 to over $200 per acre in the spring-wheat areas, is also a big item in acre-cost variation, just as is high or low yields on share-rented farms. Other items of cost were less variable, but each contributed its part to the range in acre costs as shown for these farms.

Could each wheat farmer foresee the cost per acre of production, and furthermore forecast with any degree of accuracy the yield for any given year, farming as well as cost of production studies would be much simplified. But unfortunately, this is not the case, and while such information for one year is of considerable value, it is only after data of this nature have been obtained for a number of years that plans for farm organization can be undertaken with best results. These cost figures, therefore, should be treated as preliminary, representative of but one year's work. They should be supplemented by similar figures for years to come to make them applicable as fixed standards for individual farmers.

(Further variations in the cost per acre and per bushel on farms operated by landowners are shown in Table XXXVII, appendix, where an itemized statement is recorded for each farm visited.)

VARIATION IN NET COST PER ACRE.

In figures 4 and 5 the spring-wheat and winter-wheat farms have been grouped according to cost per acre, without regard to counties. In the spring-wheat area 88 of the 197 farms came within the $20 to $25 class. Next in importance were the farms with costs ranging from $25 to $30 per acre, followed closely by the group with cost under $20 per acre. Few farms had costs of over $30.

TABLE IX.—*Variation in net cost per acre, spring and winter wheat, 1919 (481 farms).*

Net cost per acre.	Number of farms.	Cumulative per cent of farms.	Seeded.	Harvested.	Cumulative per cent harvested.	Production.	Cumulative production.	Production.
SPRING WHEAT.								
		Per cent.	*Acres.*	*Acres.*	*Acres.*	*Bushels.*	*Bushels.*	*Per cent.*
Under $20	46	23.4	10,389	10,156	23.7	62,855	62,855	17.4
$20 to $25	88	68.1	22,224	21,962	75.0	196,224	259,079	71.6
$25 to $30	50	93.4	10,066	9,440	97.0	89,432	348,511	96.3
$30 to $35	11	99.0	1,278	1,178	99.8	12,618	361,129	99.8
$35 to $40	1	99.5	210	60	99.9	423	361,552	99.9
$40 and over	1	100.0	51	51	100.0	495	362,047	100.0
WINTER WHEAT.								
Under $20	22	7.8	5,468	5,193	12.2	46,437	46,437	7.3
$20 to $25	52	26.1	11,773	11,485	39.1	141,542	187,979	29.6
$25 to $30	59	46.9	10,823	10,537	63.8	160,860	348,839	54.9
$30 to $35	65	69.7	8,343	8,206	83.0	146,151	494,990	77.9
$35 to $40	49	87.0	5,044	4,924	94.5	92,508	587,498	92.5
$40 and over	37	100.0	2,489	2,369	100.0	47,626	635,124	100.0

In the winter-wheat area the farms having costs from $30 to $35 per acre were predominant, though the variation in size of groups was much less marked than that shown by the spring-wheat farms. The

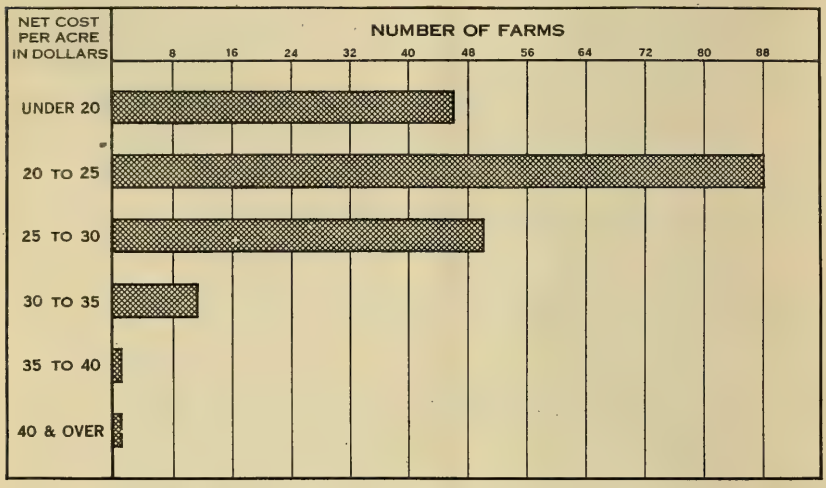


FIG. 4.—Variation in net cost per acre, spring wheat, 1919.

importance of these various groups is brought out clearly in Table IX. where the cumulative per cent of acreage harvested and cumulative per cent of production are presented.

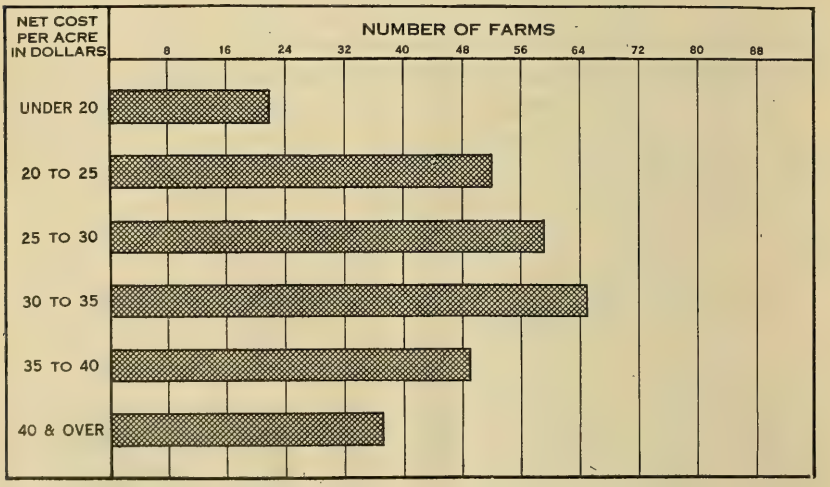


FIG. 5.—Variation in net cost per acre, winter wheat, 1919.

In the spring-wheat areas 68 per cent of the farms visited produced wheat at costs of less than $25 per acre. These farms had 75 per cent of the acreage and 72 per cent of total production.

In the winter-wheat areas the range in cost per acre was greater than in the spring-wheat areas. Nearly 70 per cent of the farmers, representing 83 per cent of the acreage and 78 per cent of total production, had costs of $35 or less per acre

NET COST PER BUSHEL.

RELATION OF YIELD TO COST PER BUSHEL.

As heretofore shown, a wide range in cost per acre existed on the farms visited. While, of course, it is advisable to produce a maximum yield at a minimum cost per acre, the ultimate result of importance is the cost of producing a bushel of wheat. If yield were to increase with fixed relation to an increase in cost per acre, a definite basis would be established for planning profitable farm organization. However, one may handle a crop according to approved methods of production only to have the crop destroyed by insects, fungus diseases, excessive droughts or rains, etc., and while the acre cost of production may be reasonable, the cost per bushel may be extremely high. The experience of wheat growers has been that if they can withstand the losses occasioned by crop failures they may hope to realize a compensating income during the good years. Were it not for a realization of these things an exceedingly bad year might induce many farmers to go out of the business.

In Tables X and XI the spring and winter wheat farms have been grouped according to yield. A review of these tables shows the influence of yield in determining cost per bushel. In general, as the yield per acre increased, the cost per bushel decreased.

TABLE X.—*Relation of yield to cost per bushel, spring wheat, 1919 (197) farms.*

Range of yield.	Number of records.	Cumulative per cent of production.	Average yield.	Average cost per bushel.	Range of yield.	Number of records.	Cumulative per cent of production.	Average yield.	Average cost per bushel.
Bushels.			*Bushels.*		*Bushels.*			*Bushels.*	
1 to 1.9	3	0.2	1.3	$12.16	10 to 10.9	11	67.0	10.3	2.30
2 to 2.9	5	.8	2.8	5.81	11 to 11.9	22	79.7	11.5	2.10
3 to 3.9	7	1.6	3.3	5.98	12 to 12.9	7	84.2	12.0	1.95
4 to 4.9	14	4.9	4.5	4.54	13 to 13.9	8	90.5	13.2	1.93
5 to 5.9	18	11.0	5.4	3.79	14 to 14.9	4	94.5	14.6	1.79
6 to 6.9	27	23.1	6.5	3.25	15 to 15.9	2	98.0	15.4	1.45
7 to 7.9	22	32.2	7.6	2.97	16 to 16.9	2	99.7	16.7	1.60
8 to 8.9	25	46.1	8.5	2.65	17 and over	1	100.0	20.8	1.15
9 to 9.9	19	55.0	9.5	2.58					

The column in these tables showing cumulative per cent of production indicates that over one-half of the wheat grown on the spring-wheat farms included in this study was produced on farms having yields of less than 10 bushels per acre, and that 45 per cent was raised on farms having yields of from 10 to 20.8 bushels per acre. In

the winter-wheat areas better yields prevailed than in the spring-wheat areas. Here nearly 50 per cent of the wheat was grown on farms having yields of from 2.2 to 16.9 bushels and the other 50 per cent was grown on farms where yields of from 17 to 30 bushels per acre were obtained. When one considers the range in yields obtained on these farms, the great variations in costs per bushel are not surprising.

TABLE XI.—*Relation of yield to cost per bushel, winter wheat, 1919 (284 farms).*

Range of yield.	Number of records.	Cumulative per cent of production.	Average yield.	Average cost per bushel.	Range of yield.	Number of records.	Cumulative per cent of production.	Average yield.	Average cost per bushel.
Bushels.			*Bushels.*		*Bushels.*			*Bushels.*	
2 to 2.9	2	0.3	2.5	$6.55	15 to 15.9	21	43.3	15.4	1.90
3 to 3.9	1	.4	3.4	4.35	16 to 16.9	18	49.4	16.4	1.82
4 to 4.9	1	.6	4.9	3.60	17 to 17.9	24	59.9	17.5	1.61
5 to 5.9	3	1.1	5.6	3.37	18 to 18.9	27	70.0	18.5	1.80
6 to 6.9	3	1.5	6.4	3.42	19 to 19.9	11	73.6	19.5	1.76
7 to 7.9	7	3.3	7.5	2.89	20 to 20.9	28	82.3	20.2	1.55
8 to 8.9	14	6.5	8.2	2.47	21 to 21.9	15	89.6	21.4	1.56
9 to 9.9	12	9.1	9.6	2.39	22 to 22.9	12	94.3	22.2	1.49
10 to 10.9	14	12.1	10.5	2.26	23 to 23.9	6	96.4	23.4	1.65
11 to 11.9	12	14.5	11.3	2.17	24 to 24.9	4	98.2	24.2	1.29
12 to 12.9	12	22.3	12.4	1.97	25 to 25.9	4	99.2	25.2	1.47
13 to 13.9	13	28.5	13.4	2.06	28 to 28.9	1	99.5	28.8	1.49
14 to 14.9	18	35.4	14.5	1.97	29 and over	1	100.0	30.0	1.46

VARIATION IN NET COST PER BUSHEL.

On the 197 spring-wheat farms the average cost was $2.65 per bushel, and the cost on individual farms ranged from $1.15 to $14.38 per bushel. However, but one of the 197 farms had a cost as high as $14.38, and only 15 farms, representing 2.5 per cent of the wheat produced, had costs exceeding $5 per bushel. In figure 6 the 197 farms have been arranged according to net cost per bushel, that the relative importance of each cost group may be shown.

The variations in net cost per bushel are due, of course, to variations in costs expended per acre and in the yields obtained, both of which factors have been previously discussed. However, it may be of interest to note conditions that prevailed in 1919 on some of the farms having extremely low or high costs. A review of the records taken indicates that when the farms were classified, as shown in figure 6, both those with comparatively low and those with comparatively high acre costs often appeared in the same cost per bushel class. Yield is the most variable factor in determining the cost of producing a bushel of wheat, and this factor is therefore largely responsible for the grouping of the farms. Farms where a part of the acreage was not worth cutting usually had a high acreage cost, owing to expenses in preparing land and seeding wheat that was not cut. Furthermore the yield from the acreage harvested was usually low, thus further increasing the bushel cost. Of the farmers having

a cost of $5 or over per bushel, about one-half abandoned a part of the seeded wheat acreage, and the yield on this group of farms ranged from slightly less than 1 bushel per acre to 7 bushels per acre, based

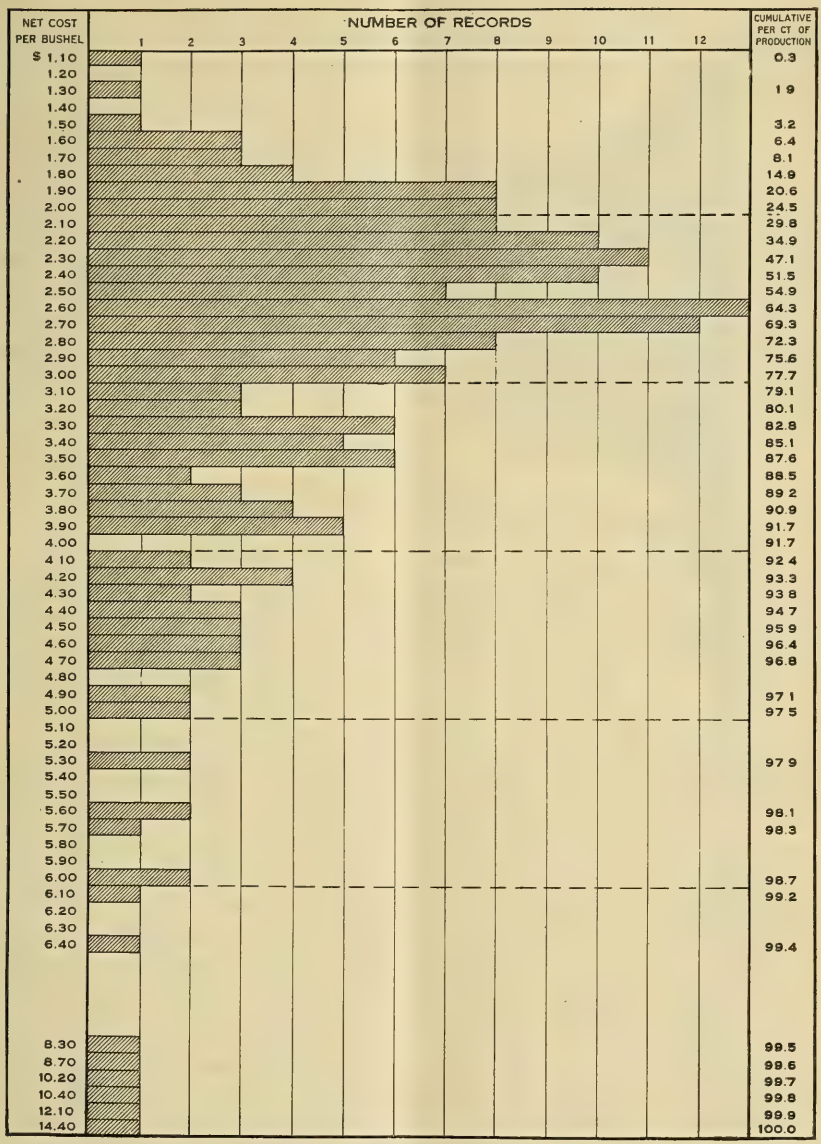


FIG. 6.—Variation in net cost per bushel, winter wheat, 1919.

on the acreage harvested. The farms having a low cost per bushel were farms on which comparatively good yields were obtained, many yielding from 10 to 15 bushels, and in some instances as high as 20 bushels per acre.

The average cost for the 284 winter wheat farms was $1.87 per bushel. The range in cost on individual farms was from $0.96 to $8.24 per bushel (see fig. 7). Nearly 75 per cent of the wheat grown

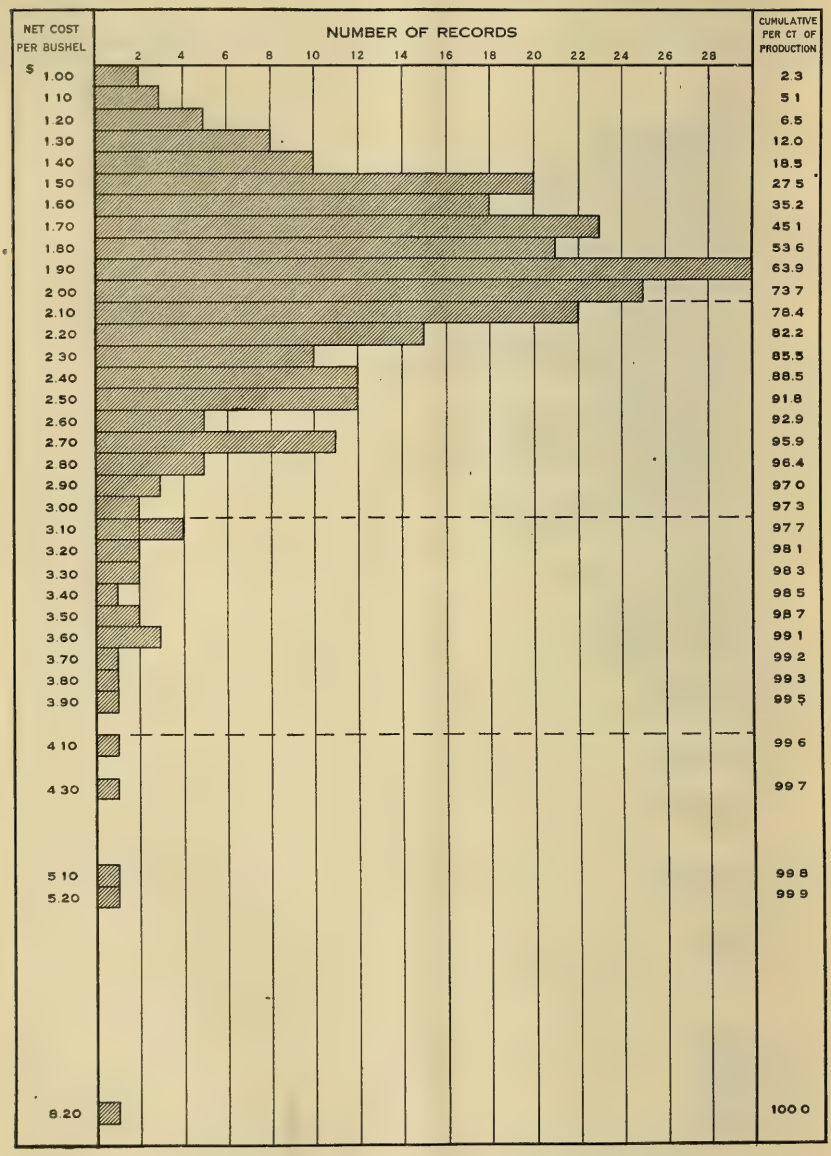


FIG. 7.—Variation in net cost per bushel, spring wheat, 1919.

on these farms in 1919 was produced at a cost of $2 and less per bushel and was grown on 165 of the 284 farms visited. As in the spring-wheat districts, good yields were obtained on the farms having low

bushel costs. A number of such farms reported yields as high as 15 to 25 bushels per acre. The farms on which the cost per bushel was exceptionally high reported yields ranging from less than 3 bushels to 8 and 10 bushels per acre. A number of the farmers with the higher costs abandoned a part of their wheat acreage because it was totally destroyed or in such condition that it was not worth the expense of harvesting.

ANALYSIS OF ITEMS OF COST.

The labor costs and other items of expense entering into the cost of wheat production have been expressed in terms of hours of labor and quantities of seed, twine, etc., wherever possible. This has been done because requirements expressed in these terms are more valuable for purposes of comparison than when expressed in the less stable terms of dollars and cents. These cost factors have been treated under the general headings, "Labor," "Material" "Thrashing," "Use cost of land," and "Other costs."

LABOR.

AVERAGE HOURS OF MAN AND HORSE LABOR PER ACRE.

Table XII shows the average number of hours per acre devoted to wheat production in the various regions studied.

The figures shown are averages for only those farms operated with horses, all farms on which the tractor or motor truck was used having been omitted in this tabulation.

The average hours per acre of man and horse labor for each district are representative, with the exception of any variation caused by different practices followed in providing labor for thrashing. In the spring-wheat areas the farmers furnished the thrashing crews in Morton, Clay, and Traverse Counties, and the total man and horse hours include all labor for hauling and pitching bundles in these counties. But in Grand Forks and Spink Counties the owner of the thrashing machine furnished the men and teams for thrashing, and this labor, which would amount to about 1¼ man and 2½ horse hours per acre, is not included in the averages shown in Table XII.

In the Kansas areas and Saline County, Mo., the crew was furnished by both farmers and thrashermen. Had the farmer furnished the entire crew the average hours of production would have been increased by about 1 man-hour per acre.

In all other winter-wheat areas, excepting Saline County, Mo., the thrashing crews, and therefore the thrashing labor, are included in the averages for these areas.

In the spring-wheat areas the average man-hours varied from nearly six hours per acre in Grand Forks County, N. Dak., to about nine hours

per acre in Morton County, N. Dak. The hours per acre of horse labor in these two counties were 19.2 and 25.7, respectively. In the winter-wheat areas a greater variation was found, man labor varying from 7.3 hours per acre in Pawnee County, Kans., to 17.5 hours in Jasper County, Mo., and horse labor from 19.7 to 39.5 hours, respectively. When the total labor was divided as to land preparation and seeding, and harvesting and marketing, it was found that in nearly every case the bulk of total horse labor came in the fall and spring when the land was prepared and the crop seeded. In the spring-wheat areas there was usually little difference in man-hours as thus divided. Generally any difference that occurred indicated that more man labor was required in land preparation and seeding than in harvesting and marketing. In the winter-wheat areas wider variations occurred in the two divisions, and usually the man-hours for harvesting and marketing were higher than for land preparation and seeding.

TABLE XII.—*Average hours of man and horse labor, by counties, spring and winter wheat, 1919 (360 farms).*

[Farms using tractors or trucks not included.]

Region.	Preparation and seeding (hours per acre).		Harvesting and marketing (hours per acre).		Total.	
	Man.	Horse.	Man.	Horse.	Man.	Horse.
SPRING WHEAT.						
North Dakota:						
Grand Forks County	3.6	14.6	2.2	4.6	5.8	19.2
Morton County	5.4	19.6	3.8	6.1	9.2	25.7
South Dakota:						
Spink County	3.1	14.8	3.0	5.3	6.1	20.1
Minnesota:						
Clay County	4.2	15.1	4.0	7.3	8.2	22.4
Traverse County	4.1	17.3	4.7	8.4	8.8	25.7
WINTER WHEAT.						
Kansas:						
Ford County	2.8	12.0	4.8	8.8	7.6	20.8
Pawnee County	2.6	11.7	4.7	8.0	7.3	19.7
McPherson County	4.5	18.8	4.8	8.1	9.3	26.9
Missouri:						
Saline County	5.1	18.5	8.1	11.1	13.2	29.6
Jasper County	8.1	26.8	9.4	12.7	17.5	39.5
St. Charles County	8.2	25.1	8.9	11.5	17.1	36.6
Nebraska:						
Phelps County	3.7	13.0	5.5	8.6	9.2	21.6
Saline County	6.7	24.7	8.1	12.4	14.8	37.1
Keith County	2.7	9.3	6.9	10.1	9.6	19.4

VARIATION IN LABOR REQUIREMENTS.

From Tables XIII and XIV it is apparent that there was a wide variation among individual farms in the amount of labor devoted to growing an acre of wheat. In these tables the farm records included in Table XII were grouped according to total man hours per acre.

In the spring-wheat areas all but eight of the 159 farms were well represented in four groups, or in those classes having man labor requirements of from 4 to 12 hours per acre. In Grand Forks and Spink Counties, nearly all of the farms came within the two groups, "4 to 6" and "6 to 8" hours per acre. In Morton County the largest group of farms required from 8 to 10 hours of man labor per acre, and in both Minnesota areas the majority of all farms showed requirements of from 6 to 10 hours per acre. Of the total wheat acreage grown on the spring-wheat farms more than one-third was grown on farms having man labor requirements of from 6 to 8 hours; also a large acreage was represented by each group of farms commencing with 4 to 6 hours per acre, and including the 10 to 12 hour group.

TABLE XIII.—*Variation in labor requirements per acre, spring wheat, 1919 (159 farms).*

[Farms using tractors or trucks not included.]

Range of man hours per acre.	North Dakota.				South Dakota.		Minnesota.				Total.		Average hours per acre.	
	Grand Forks County.		Morton County.		Spink County.		Clay County.		Traverse County.				Man.	Horse.
	Farms.	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*		
Under 4.	1	410	.....	.....	.....	.....	.....	.....	.....	.....	1	410	3.6	13.4
4 to 6...	15	3,987	2	473	15	3,350	2	520	.....	.....	34	8,330	5.1	18.1
6 to 8...	14	2,829	6	716	13	2,880	10	2,494	11	1,970	54	10,889	6.9	20.6
8 to 10..	3	719	12	1,581	1	75	10	2,267	13	2,422	39	7,064	8.7	25.5
10 to 12..	.....	.....	7	1,055	2	360	8	1,200	7	963	24	3,578	10.7	28.8
12 to 14..	.....	.....	2	225	.....	.....	.....	.....	2	160	4	385	12.9	32.8
14 to 16..	.....	.....	1	80	.....	.....	1	100	.....	.....	2	180	14.6	35.0
16 to 18..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18 to 20..	.....	.....	.....	.....	.....	.....	.....	.....	1	51	1	51	19.1	45.8
Total.	33	7,945	30	4,130	31	6,665	31	6,581	34	5,566	159	30,887	7.4	22.1

TABLE XIV.—*Variation in labor requirement per acre, winter wheat, 1919 (201 farms).*

[Farms using tractors or trucks not included.]

Range of man-hours per acre.	Kansas.						Missouri.					
	Ford County.		Pawnee County.		McPherson County.		Saline County.		Jasper County.		St. Charles County.	
	Farms.	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*
Under 4.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4 to 6.....	3	880	3	605	.....	.....	.....	.....	.....	.....	.....	.....
6 to 8.....	12	3,940	13	3,750	7	614	1	70	.....	.....	.....	.....
8 to 10.....	8	2,362	4	1,295	8	965	5	520	.....	.....	.....	.....
10 to 12.....	2	450	3	615	6	741	1	40	.....	.....	.....	.....
12 to 14.....	.....	.....	.....	.....	1	80	2	245	.....	.....	3	347
14 to 16.....	.....	.....	.....	.....	.....	.....	4	295	6	711	5	514
16 to 18.....	.....	.....	.....	.....	.....	.....	4	175	5	511	7	481
18 to 20.....	.....	.....	.....	.....	.....	.....	2	170	6	457	4	229
20 to 22.....	.....	.....	.....	.....	.....	.....	.....	.....	3	240	2	88
22 to 24.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	55
24 to 26.....	.....	.....	.....	.....	.....	.....	1	65	.....	.....	3	164
26 to 28.....	.....	.....	.....	.....	.....	.....	.....	.....	2	56	.....	.....
Total.....	25	7,632	23	6,265	22	2,400	20	1,580	22	1,975	25	1,778

TABLE XIV.—*Variation in labor requirements per acre, spring wheat, 1919 (201 farms)*—Continued.

Range of man-hours per acre.	Nebraska.						Total.		Average hours per acre.	
	Phelps County.		Saline County.		Keith County.				Man.	Horse.
	Farms.	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*	*Farms.*	*Acreage.*		
Under 4										
4 to 6	1	120					7	1,605	5.4	15.9
6 to 8	4	523			4	505	41	9,402	6.9	19.1
8 to 10	16	2,361					41	7,503	9.0	22.9
10 to 12	5	495	3	171	2	355	22	2,867	10.8	26.2
12 to 14	2	245	8	403	1	60	17	1,280	12.8	30.7
14 to 16			8	447	1	40	24	2,007	15.2	36.1
16 to 18			6	193			22	1,360	16.7	37.0
18 to 20			2	120			14	976	18.7	41.5
20 to 22			1	74			6	402	20.5	44.9
22 to 24							1	55	23.8	47.0
24 to 26							4	229	24.6	44.2
26 to 28							2	56	27.4	61.6
Total	28	3,744	28	1,408	8	960	201	27,742	10.0	24.8

In the winter-wheat areas each labor group from 6 to 20 hours per acre was well represented by farms in one or more of the counties visited. None of these farms reported less than 4 man-hours per acre, and the average for the 4 to 6 hour group was 5.4 hours. Likewise, few of the farms reported more than 20 hours per acre, although two farms with small acreages were in the 26 to 28 hour class. In the winter-wheat area the majority of farmers in the three Kansas counties and Phelps County, Nebr., reported comparatively low hours of labor per acre. The farmers in Saline County, Nebr., and Jasper and St. Charles Counties, Mo., reported comparatively high hours of labor, while those in Saline County, Mo., were fairly well distributed in all groups from 8 to 20 hours per acre. In Keith County, Nebr., but eight of the total farms were included in this tabulation because of the extensive use of tractors and employment of contract labor.

SUMMARY OF LABOR PRACTICES.

As an indication of variations in amount of labor expended per acre, a summary of labor practices is given in Tables XV to XIX inclusive.

TABLE XV.—*Summary of labor practices in the Dakotas, spring wheat, 1919.*

Practice.	Grand Forks County, N. Dak.				Morton County, N. Dak.				Spink County, S. Dak.			
	Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.	
	Per cent.	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*
Manure	72	8	9.4	21.8	67	8	10.9	20.1	72	7	11.2	27.5
Plow	100	91	1.7	9.0	85	68	2.4	12.0	98	60	2.0	10.8
Plow (tractor)	8	5	1.4	.....	13	11	1.1	.....	15	14	1.0	.....
Disk [2]	67	26	1.0	4.2	77	31	1.3	5.5	78	25	.8	3.8
Disk (tractor)	.....	.....	.....	.....	5	11	.4	.....	2	.3	.5	.....
Harrow (spike)[3]	69	65	.4	2.0	90	82	.8	3.2	98	94	.3	1.7
Harrow after drill (spike)	21	16	.2	1.0	38	36	.5	2.0	42	37	.2	1.2
Roll	21	8	.4	1.9	10	10	.6	1.9	5	18	.4	1.9
Haul seed	38	37	.1	.2	33	34	.1	.2	18	25	.1	.2
Clean seed	77	74	.3	.....	90	90	.3	.....	68	68	.2	.....
Treat seed	82	71	.1	.....	95	94	.1	.....	78	71	.1	.....
Drill seed	100	100	.5	2.0	100	100	.6	2.4	100	97	.6	2.6
Drill (tractor)	.....	.....	.....	.....	.....	.....	.....	.....	5	3	1.2	.....
Cut	100	100	.6	2.5	18	10	.7	2.7	82	68	.7	2.8
Cut (tractor)	.....	.....	.....	.....	.....	.....	.....	.....	8	10	1.1	.....
Head and stack	.....	.....	.....	.....	90	90	2.5	4.3	25	20	2.7	4.6
Head and stack (tractor)	.....	.....	.....	.....	.....	.....	.....	.....	2	2	2.4	1.3
Shock	100	100	.7	.....	18	9	.7	.....	85	79	.9	.....
Reshock	33	36	.1	.....	8	3	.2	.....	22	27	.1	.....
Shock-thrash	100	100	(4)	.....	5	3	1.3	2.6	85	81	1.0	1.9
Stack	.....	.....	.....	.....	13	8	1.6	1.9	.....	.....	.....	.....
Stack-thrash	.....	.....	.....	.....	97	a 97	.4	.....	25	19	.3	.....
Haul to granary	67	b 32	.5	.9	87	a 92	.2	.4	80	50	.6	1.1
Haul to market (from granary)	69	35	.7	2.1	90	93	.7	1.5	80	50	.8	1.6
Haul to market (from machine)	67	65	.5	1.4	13	7	.2	.5	56	50	.7	1.5

[1] Thrashing and hauling percentages are based upon bushels.
[2] Disking was done 1.3 times in Grand Forks County, 1.2 times in Morton County, and 1.1 times in Spink County.
[3] Harrowing was done 1.5 times in Grand Forks County, 1.8 times in Morton County, and 1.4 times in Spink County.
[4] Contract.
a Some grain was thrashed into bins.

TABLE XVI.—*Summary of labor practices in Minnesota, spring wheat, 1919.*

Practice.	Clay County.				Traverse County.			
	Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.	
	Per cent.	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*
Manure	77	9	10.2	31.4	76	11	11.0	29.8
Plow	85	48	2.2	11.2	93	82	2.2	11.3
Plow (tractor)	26	41	1.1	.....	12	11	1.7	.....
Disk [2]	69	26	1.1	4.5	43	14	1.5	6.0
Disk (tractor)	10	5	.6	.....	5	3	.6	.....
Harrow (spike)[3]	85	59	.4	1.8	95	93	.5	2.1
Harrow (spike) tractor	10	13	.2	.....	5	7	.2	.....
Harrow spring	5	3	.8	3.2	.....	.....	.....	.....
Harrow spring tractor	10	28	.5	.....	.....	.....	.....	.....
Harrow after drill (spike)	51	38	.2	1.0	52	57	.3	1.2
Harrow after drill tractor	5	3	.4	.....	.....	.....	.....	.....
Roll	8	4	.8	3.1	2	1	.5	2.0
Haul seed	44	50	.1	.2	17	16	.1	.2
Clean seed	79	82	.2	.....	64	61	.3	.....
Treat seed	44	36	.1	.....	79	75	.1	.....
Drill seed	100	100	.6	2.4	100	100	.6	2.4
Cut	97	88	.7	2.9	95	92	.7	2.9
Cut (tractor)	5	12	1.7	.....	7	8	1.1	.....
Shock	100	100	.9	.....	100	100	.9	.....
Reshock	46	38	.2	.....	52	47	.2	.....
Shock-thrash	100	100	1.4	2.5	86	91	1.3	2.6
Stack	.....	.....	.....	.....	14	10	2.8	3.8
Stack-thrash	.....	.....	.....	.....	14	9	.9	.....
Haul to granary	74	63	.3	.6	90	86	.4	.7
Haul to market (from granary)	74	63	.8	1.7	90	86	1.0	2.0
Haul to market (from machine)	56	37	.4	.8	24	14	.7	1.3

[1] Thrashing and hauling percentage are based upon bushels.
[2] Disking was done 1.2 times in Clay County and 1.3 times in Traverse County.
[3] Harrowing was done 1.6 times in Clay County and 1.7 times in Traverse County.

TABLE XVII.—*Summary of labor practices in Kansas, winter wheat, 1919.*

Practice.	Ford County.				Pawnee County.				McPherson County.			
	Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.	
	Per cent.	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse*
Manure	25	1	10.6	24.3	34	4	8.4	17.8	66	14	7.5	18.3
Plow	47	17	2.0	9.5	28	13	2.4	9.6	91	63	2.4	11.1
Plow (tractor)	9	6	1.2	.....	12	8	1.2	.....	20	16	1.3	.....
Plow land with cultivator	6	4	2.6	6.4	.....	.....	.....	.....	.....	.....	.....	.....
List	59	31	1.1	5.0	75	49	1.0	4.7	40	19	1.4	5.9
List (tractor)	.....	.....	.....	.....	16	8	.5	.....	.....	.....	.....	.....
Sled	59	32	1.0	3.4	78	54	.8	3.5	40	19	.9	3.8
Disk[2]	53	25	1.6	8.4	22	11	1.6	7.7	37	12	1.2	5.3
Disk (tractor)	3	3	.3	.....	3	1	1.7	.....	.....	.....	.....	.....
Harrow (spike)[3]	78	41	.4	2.0	59	44	.5	2.3	100	99	.8	3.7
Harrow (spike) tractor	.....	.....	.....	.....	6	2	.2	.....	.....	.....	.....	.....
Harrow after planting	.....	.....	.....	.....	.....	.....	.....	.....	6	13	.4	1.6
Apply grasshopper poison	56	50	.1	.2	9	7	.1	.2	3	1	.1	.....
Haul seed	88	80	.1	.2	34	25	.1	.2	34	34	.1	.2
Clean seed	22	20	.1	.....	9	7	.1	.....	43	44	.1	.....
Treat seed	6	2	.1	.....	.....	.....	.....	.....	9	9	.1	.....
Drill	100	100	.6	2.9	100	92	.7	2.9	100	100	.7	2.9
Drill (tractor)	.....	.....	.....	.....	3	8	.9	.....	.....	.....	.....	.....
Cut	62	31	.7	3.1	41	14	.8	3.6	86	78	.8	3.4
Cut (tractor)	9	5	1.2	.....	16	8	.8	.....	17	20	1.2	.....
Head and stack	84	64	3.0	4.6	97	78	3.5	5.4	3	2	3.5	4.9
Shock	69	35	1.5	.....	56	22	1.7	.....	100	98	1.1	.....
Reshock	6	4	.2	.....	3	1	.3	.....	9	6	.1	.....
Shock thrash	53	39	1.6	3.2	50	25	1.7	3.5	69	76	1.5	2.9
Stack	16	5	2.7	3.2	6	1	3.0	3.0	37	3	2.0	2.2
Stack thrash	88	61	.6	.....	97	75	(4)	(4)	40	24	(4)	(4)
Haul to granary	91	76	.7	1.3	91	a 70	.6	1.0	91	76	.5	.8
Haul to market (from granary)	91	76	1.1	2.8	91	71	.7	1.6	91	76	.9	1.7
Haul to market (from machine)	25	24	1.6	3.7	53	29	.6	1.3	31	24	1.0	1.9

[1] Thrashing and hauling percentages are based upon bushels.
[2] Disking was done 1.5 times in Ford County, 1.8 times in Pawnee County, and 1.2 times in McPherson County.
[3] Harrowing was done 1.1 times in Ford County, 1.2 times in Pawnee County, and 2.1 times in McPherson County.
[4] Contract.
a Some grain thrashed into the bins.

TABLE XVIII.—*Summary of labor practices in Missouri, winter wheat, 1919.*

Practice.	Saline County.				Jasper County.				St. Charles County.			
	Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.	
	Per cent.	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*
Haul and fill gullies	.....	.....	.....	.....	.....	.....	.....	.....	32	.....	1.4	2.3
Cut stalks	3	5	0.7	1.4	.....	.....	.....	.....	.....	.....	.....	.....
Manure	24	2	8.9	12.0	60	4	14.1	23.0	68	7	11.0	19.2
Disk before plow	14	8	1.8	7.0	3	2	1.2	4.8	.....	.....	.....	.....
Plow	79	55	3.2	11.8	93	84	3.6	12.5	82	54	4.8	15.7
Plow (tractor)	10	13	1.2	.....	17	12	2.3	.....	32	23	1.7	.....
Plow land with cultivator	3	3	.7	2.1	.....	.....	.....	.....	84	21	1.7	3.5
Disk[2]	69	43	1.3	5.3	77	51	1.4	5.4	32	16	1.9	6.8
Disk (tractor)	7	4	1.2	.....	3	5	.7	.....	8	6	.8	.....
Floating	10	8	.9	1.6	13	10	.8	3.2	5	5	.8	3.7
Drag	7	7	1.3	7.2	.....	.....	.....	.....	.....	.....	.....	.....
Harrow-spike (horse)[3]	93	86	1.1	4.2	97	99	1.4	5.6	97	81	1.6	5.8
Harrow-spike (tractor)	.....	.....	.....	.....	3	3	.3	.....	5	5	.3	.....
Harrow after drill	.....	.....	.....	.....	3	3	.4	1.6	.....	.....	.....	.....
Roll	14	9	.8	2.0	13	16	.8	2.6	37	27	.9	2.8
Ditch	.....	.....	.....	.....	.....	.....	.....	.....	13	.....	.3	.6
Haul fertilizer	3	(4)	1.0	2.0	97	99	.3	.5	.....	.....	.....	.....
Haul seed	41	39	.1	.2	37	34	.2	.4	24	19	.1	.2
Clean seed	55	55	.2	.....	100	100	.2	.....	66	62	.2	.....
Treat seed	72	76	.2	.....	3	6	.2	.....	32	24	.2	.....
Drill seed	100	100	.9	2.9	100	100	.9	2.8	100	100	1.0	2.9
Cut	97	91	1.3	5.2	100	100	.9	3.8	92	87	1.0	3.8
Cut (tractor)	7	9	1.7	.....	.....	.....	.....	.....	11	13	1.2	.....
Shock	100	100	2.3	.....	100	100	2.0	.....	100	100	2.1	.....
Reshock	76	77	.4	.....	83	87	.2	.....	87	87	.4	.....
Stack	10	7	4.4	4.0	23	20	3.4	3.9	.....	.....	.....	.....
Shock-thrash	90	94	4.9	6.0	80	81	3.3	4.0	100	100	3.4	4.1
Stack-thrash	10	6	2.6	.....	23	19	1.7	.....	.....	.....	.....	.....
Haul to granary	14	14	.4	.4	100	79	.9	1.2	66	31	.9	.6
Haul to market (from granary)	14	14	1.1	2.2	100	79	2.2	4.3	71	38	1.9	3.6
Haul to market (from machine)	86	86	1.1	2.3	37	21	1.6	3.1	76	62	2.0	2.9

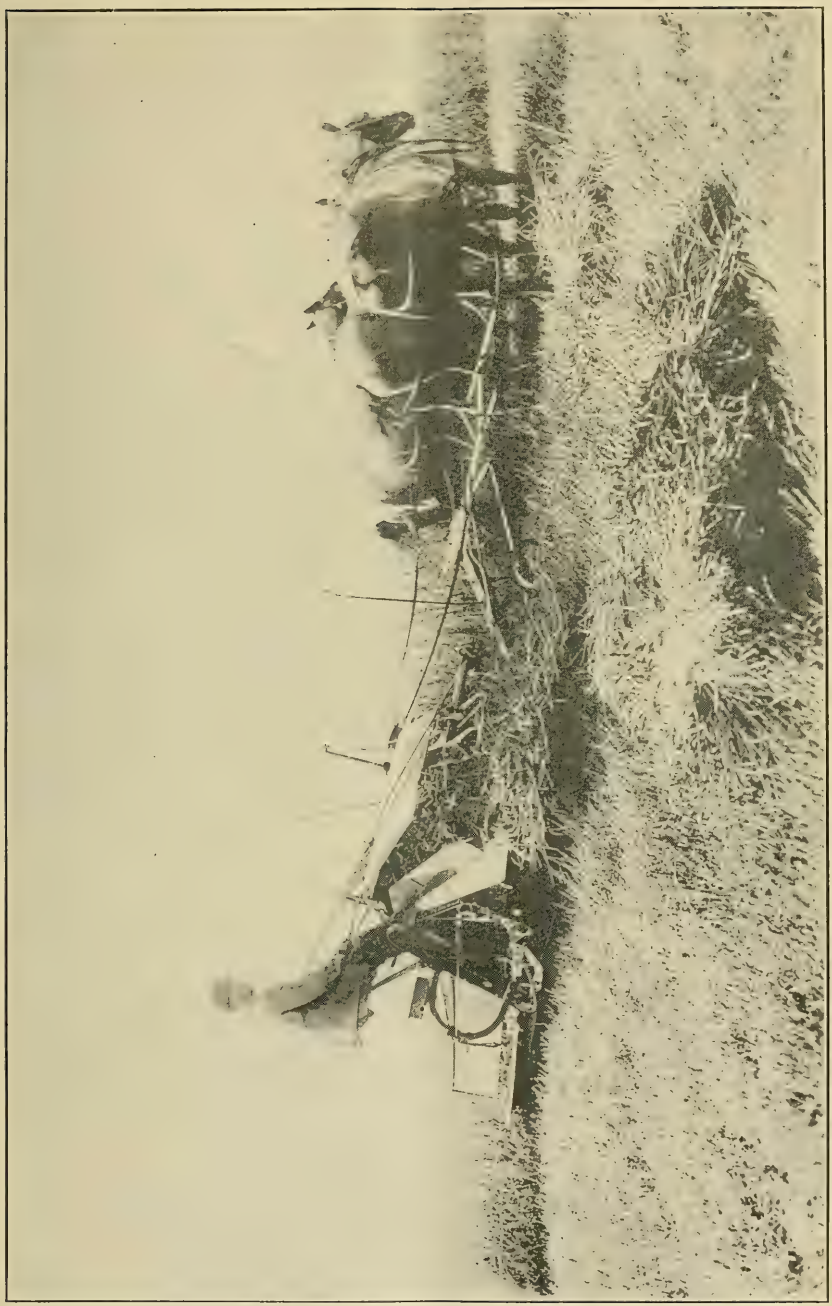
[1] Thrashing and hauling percentages are based upon bushels.
[2] Disking was done 1.3 times in Saline County, 1.2 times in Jasper County, and 1.4 times in St. Charles County.
[3] Harrowing was done 1.6 times in Saline County, 2.4 times in Jasper County, and 1.8 times in St. Charles County.
[4] Less than one-half of 1 per cent.

TABLE XIX.—*Summary of labor practices in Nebraska, winter wheat, 1919.*

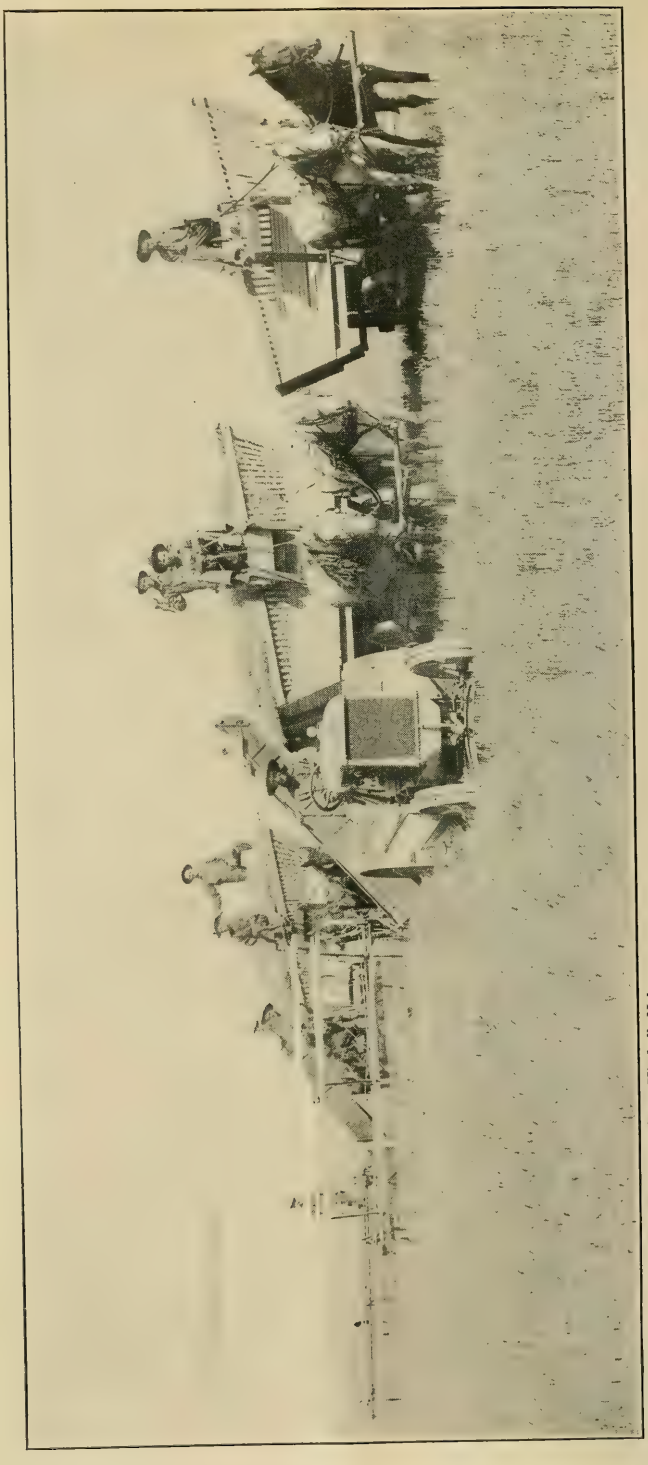
Practice.	Phelps County.				Saline County.				Keith County.			
	Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.		Records.	Acreage.[1]	Average hours per acre.	
	Per cent.	*Per cent.*	*Man.*	*Horse*	*Per cent.*	*Per cent.*	*Man.*	*Horse*	*Per cent.*	*Per cent.*	*Man.*	*Horse.*
Harrow stalks	53	18	0.4	1.8								
Cut stalks	20	5	.6	1.7								
Manure	70	7	9.1	21.3	80	17	8.5	23.8	22	1	12.7	25.4
Plow	100	61	2.3	9.5	89	74	2.9	11.2	26	6	3.6	13.7
Plow (tractor)	7	7	.9		17	24	1.3		48	57	.9	
Plow land with cultivator	3	1	1.9	7.6					4	1	1.4	1.4
Break corn stalks									39	12	.4	1.6
Break corn stalks (tractor)									4	1	.4	
Disk[2]	33	16	.8	3.6	69	56	1.4	5.8	48	23	2.3	9.7
Disk (tractor)									30	40	.8	
Harrow (spike)[3]	100	65	.6	2.5	100	99	.7	2.8	26	14	.5	1.9
Harrow (spike) (tractor)									4	1	.4	
Harrow after drill					3	1	.4	1.6				
Roll	3	.2	.4	1.6	6	3	.8	3.4				
Apply grass-hopper poison	30	24	.1	.1								
Haul seed	17	21	.1	.2	9	6	.2	.4	13	22	.1	.2
Clean seed	30	23	.1		54	54	.2		52	60	.1	
Treat seed	10	8	.1		3	3	.1		35	31	.1	
Drill seed	97	97	1.1	3.0	100	100	.9	3.6	70	46	1.2	3.3
Drill seed (tractor)	3	3	.6						30	54	.7	
Cut	93	90	.7	3.5	100	93	.9	3.9	39	32	.8	3.3
Cut (tractor)	7	9	1.2		3	7	1.2		30	45	.9	
Head and stack	3	1	3.5	5.0					35	15	2.3	3.9
Head and stack (tractor)									4	8	2.2	1.6
Shock	99	99	1.0		100	96	1.6		65	71	1.3	
Re-shock	37	38	.2		46	42	.2		26	36	.3	
Stack	37	28	2.6	2.9	6	2	4.2	4.8	22	9	2.8	2.7
Shock thrash	63	73	1.9	2.5	94	98	3.5	5.0	52	70	2.6	3.3
Stack thrash	40	27	.9		6	2	1.4		52	30	1.3	
Haul to granary	83	59	.3	.5	89	66	.8	1.2	78	69	.8	1.3
Haul to market (from granary)	83	59	1.0	2.0	89	66	1.5	3.0	78	69	2.2	4.6
Haul to market (from machine)	60	41	.8	1.6	46	34	1.4	2.5	35	31	.6	.8

[1] Thrashing and hauling percentage are based upon bushels.
[2] Disking was done 1.0 time in Phelps County, 1.4 times in Saline County, and 2.1 times in Keith County.
[3] Harrowing was done 1.9 times in Phelps County, 1.9 times in Saline County, and 1.3 times in Keith County.

Plowing is an operation that requires a large amount of power and labor as compared with other farm operations. In the spring-wheat area 86 per cent of the total wheat acreage was plowed, and of this 20 per cent was plowed with tractor power. The remaining 14 per cent of the wheat acreage was corn stubble and potato land which was not plowed but usually disk-harrowed instead. Clay County, Minn., was foremost in the use of the tractor for plowing, 41 per cent of the acreage being tractor-plowed in this area. In the various winter-wheat areas visited a wide variation existed in the percentage of total wheat acreage plowed. In Pawnee and Ford Counties, Kans., but 21 and 23 per cent, respectively, of the wheat land was plowed, while in the other districts from 60 to 98 per cent was plowed. The tractor was extensively used in St. Charles County, Mo., where 24 per cent of the land was plowed by tractor power. In Ford, Pawnee, and McPherson Counties the lister was substituted



THE GRAIN BINDER IS MOST COMMONLY USED FOR HARVESTING WHEAT IN THE SPRING-WHEAT AREA.



Photograph by courtesy of Bergman Brothers, Kimball, Nebr.

A HEADER OUTFIT THAT COVERS A LARGE ACREAGE PER DAY IN HARVESTING WHEAT.

for the plow on a part of the wheat acreage. (See fig. 8.) In Ford County 31 per cent of the wheat area was listed; in Pawnee County 50 per cent; and in McPherson County 19 per cent of the land was broken in this manner. After listing a "ridge buster," or "sled," as it is commonly called, was used for the purpose of tearing down the ridges or rows left by the lister. In some of the areas a part of the corn stubble land was prepared for seeding by running over it with a two-horse disk cultivator. In St. Charles County, Mo., 21 per cent of the wheat acreage was gone over with the disk cultivator. The disk harrow was extensively used in some areas for all preparation prior to drilling. On some farms a part of the grain stubble and corn land received no preparation, but was seeded with

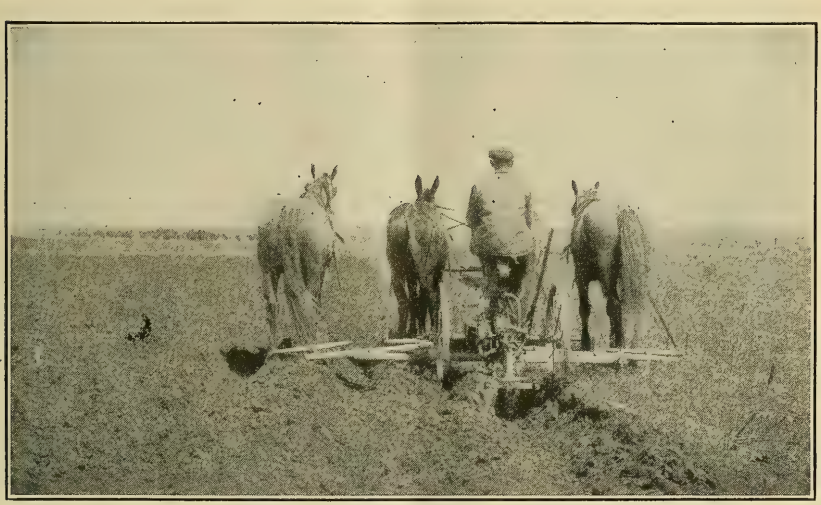


FIG. 8.—Preparation of land for wheat with the one-row lister.

a disk drill, which served the purposes of preparing the land and seeding in one operation. (See fig. 9.)

The spike-tooth harrow was used extensively in both spring and winter wheat areas. In the spring-wheat areas 76 per cent of the entire acreage was spike-harrowed before seeding, and 30 per cent of this acreage was harrowed again after seeding. The spike-tooth harrow was also commonly used in the winter-wheat areas, but none of this work was reported after seeding.

In the spring-wheat districts 83 per cent of the acreage was cut with a binder and 17 per cent was headed. (See Pl. I.) Of the total acreage harvested, 6 per cent was cut with tractor power. All work with the header was reported from Morton County, N. Dak., and Spink County, S. Dak. In these two areas 88 and 20 per cent, respectively, of the total acreage was headed. In the winter-wheat

districts 66 per cent of the total wheat acreage was harvested with the binder and 34 per cent was headed. Tractor power was used in harvesting grain in all areas excepting Jasper County, Mo. Of the winter-wheat acreage 13 per cent was cut with tractor power. Heading was found to be most common in Ford and Pawnee Counties, Kans. About 64 per cent of the Ford County acreage and 78 per cent of the Pawnee County acreage was harvested with the header (see Pl. II).

In both spring and winter wheat regions most of the bundle grain was shock thrashed. The headed grain was stacked before thrashing. The grain was either hauled direct from the thrashing machine to local elevators and railroad cars or stored on the farm. In some localities grain elevators were soon filled, railroad cars were not

FIG. 9.—Disking stubble land preparatory to drilling wheat without further preparation.

available at thrashing time, and adequate storage facilities were not available on the farm, so that a part of the wheat was often dumped in piles on the ground until marketing and storage facilities became available.

In every case all labor and expenses incident to storing and hauling grain to market have been included in the cost of production.

LABOR RATES.

Man-labor rate.—The man-labor rates, as shown in Table XX, are based on prevailing month and day wages paid for farm labor at the time the work was done, including board, when furnished. The labor of the farmer and any members of his family was charged at the same rate. The labor prior to harvesting was mainly performed by the farmer, with the aid of month hands. During the harvest period, however, because of the scarcity of harvest hands

and the transient character of labor employed, practically all labor was hired on a day basis at a much higher wage. For this reason different rates have been used for seed-bed preparation and seeding and for harvesting and marketing. The wage paid was mainly governed by the competition for farm labor at the time the work was done; it will be noted that there is considerable variation in the rates used in the several districts visited.

Horse-labor rate.—The horse-labor rates, as shown in Table XX, are based partially on the prevailing charge for team work in the regions visited, and partially on the cost of horse labor as obtained from detailed cost records which were available for some of the States in which this investigation was made. It will be noted that the horse-labor rate in Ford County, Kans., was higher than in other districts visited; this was due to partial crop failures in 1918 and 1919, which resulted in a relatively high cost of grain and roughage.

TABLE XX.—*Man and horse labor rates per hour, spring and winter wheat, 1919 (481 farms).*

State and county.	Seed-bed preparation and seeding.		Harvesting and marketing.	
	Man rate.	Horse rate.	Man rate.	Horse rate.
SPRING-WHEAT AREAS.				
North Dakota:				
Grand Forks County	$0.35	$0.20	$0.60	$0.20
Morton County	.35	.20	.60	.20
South Dakota:				
Spink County	.40	.20	.65	.20
Minnesota:				
Clay County	.35	.20	.60	.20
Traverse County	.35	.20	.60	.20
WINTER-WHEAT AREAS.				
Kansas:				
Ford County	.35	.25	.75	.25
Pawnee County	.30	.18	.60	.18
McPherson County	.35	.20	.75	.20
Missouri:				
Saline County	.30	.18	.60	.18
Jasper County	.30	.18	.50	.18
St. Charles County	.25	.18	.55	.18
Nebraska:				
Phelps County	.35	.20	.65	.20
Saline County	.35	.20	.70	.20
Keith County	.35	.20	.80	.20

AVERAGE LABOR COST PER ACRE.

The labor cost, as shown in Table XXI, includes all man-and-horse labor expended by the farmer and any contract labor hired. All work in which the farmer's men and horses had no part has been recorded as contract labor. This includes a small amount of plowing for which the farmer paid a stipulated sum per acre for man and horses or tractor and plows; a small amount of cleaning seed wheat; a nominal amount of cutting wheat with the grain binder; and some marketing grain, which was usually hauled with a truck at a fixed charge per bushel per mile hauled. The relatively

high charge for contract labor in Keith County, Nebr., was largely due to the great amount of grain hauled to market by contract labor, this being 66 per cent of all that was produced.

In some districts considerable work was done with tractors. Unless contract work, the man hours for operating the tractor were included under labor costs; but obviously no cost for horse labor would occur. The maintenance and upkeep cost of the tractor have been charged under machinery costs and not as hours of tractor labor.

The great variations in average labor costs, by counties, as shown in Table XXI, are due to the variation in man and horse labor rates used in calculating labor costs, and to the variations in amounts of labor devoted to raising an acre of wheat. As previously shown, considerable variation existed in the average labor rates determined for various counties. However, it does not necessarily follow that those counties having the higher labor rates had the higher total labor costs per acre.

TABLE XXI.—*Average cost per acre of labor, by counties, spring and winter wheat, 1919 (481 farms).*

Region.	Direct man-and-horse labor cost.	Contract labor cost.	Total cost.
North Dakota:			
Grand Forks County	$6.18	$0.11	$6.29
Morton County	8.41	.06	8.47
South Dakota:			
Spink County	6.72	.07	6.79
Minnesota:			
Clay County	7.26	.03	7.29
Traverse County	8.87	.03	8.90
All spring wheat	7.30	.07	7.37
Kansas:			
Ford County	9.62	.04	9.66
Pawnee County	6.78	.02	6.80
McPherson County	10.70	.02	10.72
Missouri:			
Saline County	11.19	.23	11.42
Jasper County	13.41	.22	13.63
St. Charles County	12.37	.....	12.37
Nebraska:			
Phelps County	8.99	.....	8.99
Saline County	14.72	.01	14.73
Keith County	7.69	1.50	9.19
All winter wheat	9.66	.19	9.85

MATERIALS.

SEED.

The most common variety of seed wheat for the spring-wheat districts was the Marquis, and for the winter-wheat districts the Turkey Red. An average of approximately 3.5 per cent of the winter-wheat acreage was reseeded, while no reseeding was required for spring wheat.

The rate of application is the average for one seeding only, but the cost per acre includes the value of the seed used on the reseeded acreage. For this reason, and also because the acre cost for seed is a weighted average, the average amount applied per acre multiplied by the average price per bushel will not equal the cost per acre.

The value of seed wheat per bushel is an average. Some men bought high-grade recleaned seed and some used their own supply for planting. The figures given include the value of any materials used for seed treatment. All farm-grown seed was charged at its farm sale value at planting time.

The average rate of seeding and the average price per bushel were somewhat less for the winter wheat than for the spring wheat, with a correspondingly lower cost per acre for winter wheat. (See Table XXI.)

BINDER TWINE.

Because of the light straw, the average binder-twine requirements per acre were appreciably less in the spring-wheat than in the winter-wheat districts.

In three spring-wheat and in four winter-wheat districts the entire acreage was cut with a binder. Principally because of the short straw in Morton County, N. Dak., 90 per cent of the acreage was cut with a header. The average price paid for twine varied from 22 cents per pound in Clay County, Minn., to 29 cents in Grand Forks County, N. Dak., and the average for all winter wheat was 1 cent per pound higher than for all spring wheat. (See Table XXIII.)

TABLE XXII.—*Seed requirements per acre, spring and winter wheat, 1919 (481 farms).*

State and county.	Per cent of acreage re-seeded.	Rate of application.	Price per bushel.	Average cost per acre.
North Dakota:		*Bushels.*		
Grand Forks County	.....	1.39	$2.44	$3.39
Morton County	.....	1.23	2.41	2.98
South Dakota:				
Spink County	.....	1.20	2.32	2.78
Minnesota:				
Clay County	.....	1.36	2.44	3.45
Traverse County	.....	1.41	2.41	3.38
All spring wheat	.....	1.31	2.40	3.21
Kansas:				
Ford County	4.4	.77	2.23	1.79
Pawnee County	9.8	.95	2.12	2.19
McPherson County	1.4	1.06	1.98	2.36
Missouri:				
Saline County	.....	1.30	2.10	2.73
Jasper County	.2	1.23	2.05	2.52
St. Charles County	.....	1.14	2.21	2.58
Nebraska:				
Phelps County	1.4	1.04	2.06	2.13
Saline County	.....	1.44	2.09	2.99
Keith County	.....	.92	2.05	1.72
All winter wheat	3.4	1.11	2.12	2.18

TABLE XXIII.—*Binder twine requirements, spring and winter wheat, 1919 (481 farms).*

State and county.	Per cent of acreage cut with binder.	Amount used per acre.	Cost per pound.	Cost per acre.
North Dakota:		*Pounds.*		
Grand Forks County	100	1.91	$0.29	$0.57
Morton County	10	1.32	.25	.33
South Dakota:				
Spink County	78	1.98	.25	.50
Minnesota:				
Clay County	100	2.21	.22	.50
Traverse County	100	2.00	.23	.46
All spring wheat	83	2.03	.25	.51
Kansas:				
Ford County	36	3.49	.25	.87
Pawnee County	22	3.23	.28	.91
McPherson County	98	2.80	.23	.64
Missouri:				
Saline County	100	2.85	.23	.66
Jasper County	100	2.32	.23	.53
St. Charles County	100	2.26	.25	.55
Nebraska:				
Phelps County	99	2.68	.24	.63
Saline County	100	3.69	.24	.87
Keith County	77	2.31	.25	.58
All winter wheat	66	2.80	.24	.68

MANURE AND STRAW.

When manure is applied to a particular crop, other crops following in the rotation get part of the benefit. This cost then should be distributed among the different crops grown. When applied directly to wheat, 50 per cent of the estimated value was charged; when applied to the crop immediately preceding, 30 per cent was charged; and when two other crops preceded, 20 per cent was charged to the wheat.

The largest number of farmers reporting the use of manure (80 per cent) was for Saline County, Nebr., while the smallest number was for Keith County, Nebr. In Ford County, Kans., and Keith County, Nebr., only 1 per cent of the total wheat acreage was manured. Farmers in these counties regard manure and straw of more value for top dressing to conserve moisture and prevent "blowing" of the land than as a fertilizer. In these two counties not enough moisture is available to make manure valuable as a fertilizer.

For the spring-wheat districts 8 per cent of the total wheat acreage received an application of manure and straw, while for the winter wheat only 5 per cent of the total acreage was covered. (See Table XXIV.)

GREEN MANURE.

In St. Charles County, Mo., it is a common practice to plow under a certain number of acres of new clover seeding each year. Corn is usually grown on this land for one or two years, followed by wheat for one or two years more. It will be readily seen that this practice

results in material benefit to the crops which follow. From each farmer an estimate was obtained relative to the amount of clover seed used and the time required to sow this seed on the average amount of new seeding plowed under each year; also the crops following on this land were noted. With these data available a charge for the value of the clover seed used and the time required to sow it was computed, which amounted to $2.80 per acre. This cost was prorated to the crops receiving benefit. In the case of wheat this charge amounted to $0.33 per acre.

TABLE XXIV.—*Straw and manure applied per acre, spring and winter wheat, 1919 (481 farms).*

State and county.	Per cent of farmers reporting.	Per cent of total acreage covered.	Rate of application per acre.	Cost per acre actually covered.
North Dakota:			*Tons.*	
Grand Forks County	72	8	10.28	$5.09
Morton County	67	8	6.84	5.66
South Dakota:				
Spink County	72	7	9.91	6.65
Minnesota:				
Clay County	77	9	13.67	10.84
Traverse County	76	11	11.41	6.44
All spring wheat	73	8	10.53	6.96
Kansas:				
Ford County	25	1	8.90	10.77
Pawnee County	34	4	9.52	5.41
McPherson County	60	14	6.40	5.38
Missouri:				
Saline County	24	2	6.50	5.44
Jasper County	60	4	9.43	7.96
St. Charles County	68	7	9.24	6.94
Nebraska:				
Phelps County	70	7	8.23	2.57
Saline County	80	17	7.84	2.45
Keith County	22	1	4.95	3.96
All winter wheat	51	5	7.98	4.87

COMMERCIAL FERTILIZER.

Commercial fertilizer was not used in any of the areas visited except Missouri, and in this State to no appreciable extent except in Jasper County. In this county 97 per cent of the men interviewed used commercial fertilizer on their entire wheat acreage, and 3 per cent used no fertilizer on this crop. The quantity applied averaged 100 pounds per acre and the average cost was $42 per ton.

In St. Charles and Saline Counties commercial fertilizer on wheat was not reported except on one farm in each county, where a very small acreage was fertilized, more as an experiment than as a regular practice.

GRASSHOPPER CONTROL.

In Ford County, Kans., much wheat was destroyed by grasshoppers. To control these pests a mixture in the proportion of about 20 pounds of bran, 1 pound of arsenic or Paris green, ½ gallon of

molasses, and 2 oranges or lemons was used. Some of the poison was furnished gratis by the county, so only such poison as was purchased by the farmer is given on the records. Twelve men in Ford County, Kans., and 13 in Phelps County, Nebr., reported the use of grasshopper poison; on these farms this charge was of little importance, and, prorated over the entire acreage surveyed, amounted to but 2 cents per acre in Ford County and 1 cent in Phelps County.

TABLE XXV.—*Thrashing practices and costs, spring and winter wheat, 1919 (481 farms).*

State and county.	Prevailing thrashing practices.					Average cost per acre for the region.
	Thrashing done from—	Part of crew[1] furnished by—		Per cent of production.	Average rate per bushel.	
		Thrasherman.	Farmer.			
SPRING WHEAT.						
North Dakota:						
Grand Forks County	Shock	All		100	$0.27	$2.78
Morton County	Stack		All	100	.10	.43
South Dakota:						
Spink County	Shock	All		92	.27	2.68
Minnesota:						
Clay County	Shock		All	97	.13	1.18
Traverse County	Shock		All	99	.13	1.13
WINTER WHEAT.						
Kansas:						
Ford County	Stack	All		57	.20	2.58
	Shock	Field pitchers	Bundle haulers	43	.19	
Pawnee County	Stack	All		75	.20	2.67
	Shock	Field pitchers	Bundle haulers	25	.19	
McPherson County	Stack	All		25	.24	2.83
	Shock	Field pitchers	Bundle haulers	75	.22	
Missouri:						
Saline County	Shock		All	63	.16	3.37
	Shock	All		37	.29	
Jasper County	Shock		All	100	.08	1.45
St. Charles County	Shock		All	100	.10	1.86
Nebraska:						
Phelps County	Shock		All	99	.11	1.18
	Stack		All			
Saline County	Shock		All	100	.11	1.98
Keith County	Shock		All	92	.10	1.91
	Stack		All			

[1] In every case the thrasherman furnished the crew for operating the separator and engine and the farmer furnished the men and horses for taking care of the thrashed grain.

THRASHING PRACTICES AND COSTS.

The main thing which determined the rate per bushel paid for thrashing was the proportion in which the thrashing crew was furnished by the farmer and the thrasherman. (See Table XXV.) In some regions the wheat yields varied so greatly that thrashing was paid for on an hour basis rather than a bushel basis, and of course farms with low yields had a comparatively high thrashing rate per bushel.

In three of the spring-wheat districts the farmers usually furnished all of the thrashing crew, and the average thrashing rate varied from 10 cents per bushel in Morton County, N. Dak., to 13 cents in both of the other two counties. In Grand Forks County, N. Dak., and

Spink County, S. Dak., the thrasherman usually furnished the thrashing crew, and the average rate for thrashing was 27 cents per bushel in both counties.

In the Kansas areas the farmers furnished the bundle haulers and teams and the thrasherman furnished field pitchers, where shock thrashing was done; where the grain was thrashed from the stack, the grain pitchers were furnished by the thrasherman. In any case, the crew furnished by the thrasherman did not vary to any marked extent, and the rate per bushel was fairly uniform, being slightly higher for stack thrashing.

In Saline County, Mo., 63 per cent of the production was thrashed with the farmer's crew and 37 per cent with the thrasherman's crew. The rates were 16 cents and 29 cents a bushel. In the other winter-wheat areas the thrashing crews were furnished by the farmers in nearly every case and the rates averaged from 8 cents to 11 cents a bushel.

The average cost per acre varied in each region according to yield and rate per bushel. The average acre cost for all winter wheat was 52 cents greater than the average for all spring wheat, but the average bushel cost was 4 cents less for winter wheat.

USE-COST OF LAND OR LAND RENT.

An estimate of the value of the land on which wheat was grown was obtained from each farmer visited. The current interest rate on first mortgages was also determined for each district. The result obtained by multiplying the investment in wheat land by the interest rate was used as the charge for use of land on owned farms. If the land was rented on a cash basis the actual cash rent paid per acre was used. If the land was share-rented the value of any items furnished by the landlord, such as seed, twine, thrashing, crop insurance, etc., was charged as a cost to the operator; these items were then deducted from the value at thrashing time of the share of wheat given to the landlord, the difference appearing as the operator's cost for the use of land. The one-half share rent system predominated in the Spring-Wheat Belt, and the one-third share rent system was most common in the Winter-Wheat Belt. Approximately 30 per cent of the spring-wheat acreage was rented on a one-half share basis and 62 per cent of the wheat land was owned by the operator. About 47 per cent of the winter-wheat acreage was one-third share-rented and 42 per cent of the wheat land was owned by the operator.

On owned farms the market value of the wheat land influenced the land-rent charge. On share-rented land the yield per acre, the share given as rent, and the part of the expenses paid by the landlord are the dominating factors.

In the spring-wheat areas the interest on investment exceeded the value of share-rent paid, while in the winter-wheat districts the reverse was true.

TABLE XXVI.—*Use-cost of land per acre, spring and winter wheat, 1919 (481 farms).*

State and county.	Owned land.		Rented land.				
	Value per acre.	Interest on investment.	One-half share.	One-third share.	Two-fifths share.	One-fourth share.	Cash.
North Dakota:							
Grand Forks County	$80	$4.79	$3.43	$4.56	.....	.....	$4.92
Morton County	36	2.16	2.65	2.87	.....	$1.57	1.25
South Dakota:							
Spink County	134	8.06	7.50	3.30	.....	3.35	.....
Minnesota:							
Clay County	137	8.20	3.80	3.31	.....	.....	3.53
Traverse County	108	6.50	4.24	5.55	.....	.....	3.00
All spring wheat	100	6.00	4.90	3.58	.....	2.02	3.52
Kansas:							
Ford County	55	3.28	9.96	9.12	.....	3.87	.....
Pawnee County	87	5.23	9.49	9.09	$11.26	.....	6.00
McPherson County	134	8.06	.....	8.34	12.27	.....	7.05
Missouri:							
Saline County	241	14.44	13.60	13.49	18.08	.....	7.82
Jasper County	135	8.09	.....	11.98	.....	.....	.....
St. Charles County	173	10.38	.....	13.77	20.26	.....	9.90
Nebraska:							
Phelps County	123	7.37	.....	6.70	.....	.....	.....
Saline County	213	12.80	.....	12.27	15.06	.....	.....
Keith County	92	5.53	.....	11.67	.....	.....	.....
All winter wheat	122	7.33	10.90	9.50	14.13	3.87	8.33

Because of the lower land values and lower yield of wheat in the Spring-Wheat Belt, the charge for the use of land is considerably lower there than in the Winter-Wheat Belt. (See Table XXVI.)

OTHER COSTS.

TAXES AND INSURANCE.

An estimate was obtained from each man interviewed concerning his real estate, live stock, and equipment investment. On owned land the per cent that the investment in wheat land is of this total investment represents the proportion of the total farm taxes and insurance that has been charged to the wheat land. On rented farms, land taxes and building insurance were paid by the landlord. Any other taxes and insurance were paid by the renter and have been charged against live stock and equipment, wheat receiving its proportionate share through the equipment charge.

The average tax and insurance charge on owned land varied from 25 cents per acre in Morton County, N. Dak., to 95 cents in Saline County, Nebr.

The special crop insurance includes fire insurance on stacked and stored grain and hail insurance on the growing crop. In Morton

and Grand Forks Counties there is a State hail insurance tax of 3 cents on each tillable acre owned. Furthermore, there is an additional tax on all acreage insured, the amount of the assessment to be adjusted at the end of the year in the same manner as mutual fire insurance companies.

TABLE XXVII.—*Taxes and insurance, spring and winter wheat, 1919 (481 farms).*

State and county.	Taxes and insurance on owned land.		Special crop insurance.	
	Per cent of farmers owning land.	Cost per acre.	Per cent of farmers reporting.	Average cost per acre insured.
North Dakota:				
Grand Forks County	62	$0.53	100	$0.18
Morton County	95	.25	100	.21
South Dakota:				
Spink County	72	.62	69	.40
Minnesota:				
Clay County	68	.84	76	.81
Traverse County	86	.53	29	.43
All spring wheat	76	.56	74	.39
Kansas:				
Ford County	72	.30	91	1.21
Pawnee County	53	.54	94	1.32
McPherson County	37	.72	63	.42
Missouri:				
Saline County	73	.70	21	.29
Jasper County	57	.56	63	.15
St. Charles County	82	.53	26	.19
Nebraska:				
Phelps County	47	.48	87	.74
Saline County	77	.95	29	.75
Keith County	56	.37	78	1.43
All winter wheat	62	.52	60	1.00

The largest acre charge for special crop insurance was made in Ford and Pawnee Counties, Kans., and in Keith County, Nebr. In these counties a relatively large hail insurance was carried on the growing crop. (See Table XXVII.)

USE-COST OF TRACTOR.

The annual use-cost of a tractor includes repairs, fuel, oil, interest, taxes and insurance, and depreciation. This yearly cost divided by the total number of days the tractor was used during the year gave the average daily cost of running the tractor. The daily cost multiplied by the number of days the tractor was used on wheat production gave the total tractor use-cost chargeable to wheat. All man labor costs involved in running the tractor have been included under man-labor requirements and do not appear as a tractor charge. Table XXVIII shows the principal work on wheat performed by the tractor and the normal man-labor requirements and costs per acre for these operations. The use of the tractor was more common in

the winter wheat than in the spring wheat areas. The highest cost per acre for tractor use occurred in Keith County, Nebr., where over 50 per cent of the men interviewed used the tractor. In this area 30 per cent of the farmers used the tractor for harvesting wheat with the binder and 4 per cent used the tractor for heading wheat. (See fig. 11.)

USE-COST OF OTHER FARM MACHINERY.

The items making up the total charge for use of "other farm machinery" include taxes and insurance, interest on investment, depreciation, and the annual maintenance repairs for this machinery. The total annual farm charge for the use of machinery has been divided between the crop and live-stock enterprises on the farm in proportion to the number of horse hours of work required in their production. In a few instances farm machinery was hired for use in producing the wheat crop and when this was the case the actual cash paid out was considered.

TABLE XXVIII.—*Use cost of tractor and other farm machinery spring and winter wheat, 1919 (481 farms).*

State and county.	Plowing (tractor work).			Disking (tractor work).			Harrowing (tractor work).			Cutting (tractor work).			Annual use-cost of other farm machinery.
	Per cent reporting.	Hours per acre.	Cost per acre.	Per cent reporting.	Hours per acre.	Cost per acre.	Per cent reporting.	Hours per acre.	Cost per acre.	Per cent reporting	Hours per acre.	Cost per acre.	
SPRING WHEAT.													
North Dakota:													
Grand Forks County	7.7	1.1	$1.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	$1.50
Morton County	12.8	1.1	1.30	5.1	0.7	$0.45	.....	.....	.....	.....	.....	.....	1.98
South Dakota:													
Spink County	15.0	1.0	1.34	2.5	.5	.50	.....	.....	.....	7.5	0.4	$0.47	1.36
Minnesota:													
Clay County	25.6	1.1	1.37	10.3	.6	.52	20.5	0.3	$0.41	5.1	.2	.50	1.30
Traverse County	11.9	1.2	1.31	4.8	.6	.53	4.8	.2	.26	7.1	.5	.43	1.43
WINTER WHEAT.													
Kansas:													
Ford County	9.0	.9	1.36	3.1	.3	.65	.....	.....	.....	9.4	.5	.49	1.15
Pawnee County	12.5	1.1	1.59	3.1	.8	.65	6.2	.2	.21	15.6	.6	.50	1.32
McPherson County	20.0	1.1	1.28	.....	.....	.....	.....	.....	.....	17.1	.7	.56	1.91
Missouri:													
Saline County	10.0	1.2	1.30	6.9	1.2	.60	.....	.....	.....	6.9	.7	.41	1.51
Jasper County	16.7	2.0	1.46	3.3	.7	.60	3.3	.3	.25	.....	.....	.....	1.77
St. Charles County	31.6	1.6	1.50	7.9	.8	.73	5.3	.3	.30	10.5	.6	.45	2.13
Nebraska:													
Phelps County	6.7	.7	.97	.....	.....	.....	.....	.....	.....	6.7	.4	.48	1.23
Saline County	17.1	1.3	1.43	.....	.....	.....	.....	.....	.....	2.9	.6	.50	1.93
Keith County	47.8	.9	1.34	30.4	.8	.48	4.3	.4	.35	30.4	.3	.48	1.68

LOSS ON ABANDONED WHEAT ACREAGE.

On some farms visited a part of the acreage seeded to wheat was not harvested because the crop was destrayed or in such condition that it was not worth cutting. All costs for labor, seed, manure,

use of land, unless recropped, taxes and insurance, etc., expended on this acreage make up the charge "Loss on abandoned wheat acreage." When pastured, credit has been given for the value of the pasture. The total cost of all abandoned acreage in a region, divided by the acreage harvested, is the average abandoned acreage cost per harvested acre. (See Table XXIX.)

In South Dakota, Minnesota, St. Charles County, Mo., and Keith County, Nebr., no abandoned acreage was reported, while in the other areas from 0.5 to 8.2 per cent of the wheat acreage was not harvested.

SACK RENT.

During thrashing in Saline and St. Charles counties, Mo., a part of the wheat was sacked and stored on the farm until thrashing was over, or hauled direct to local elevators. In many instances the farmers did not own sufficient sacks and rented additional ones. The rent for the use of these amounted to about 4 cents per sack, and the acre charge for sack rent averaged about 7 cents an acre for each county.

TABLE XXIX.—*Loss due to abandoned wheat acreage, spring and winter wheat—1919 (481 farms).*

State and county.	Per cent of farms reporting abandoned acreage.	Acres seeded.	Acres harvested.	Per cent of total acreage abandoned.	Average cost per acre abandoned.
North Dakota:					
Grand Forks County	28	10,959	10,060	8.20	$10.87
Morton County	28	6,312	5,840	7.48	11.64
South Dakota:					
Spink County	.....	9,500	9,500	.....	.....
Minnesota:					
Clay County	.....	10,376	10,376	.....	.....
Traverse County	.....	7,071	7,071	.....	.....
All spring wheat	11	44,218	42,847	3.10	11.14
Kansas:					
Ford County	19	10,164	9,817	3.41	6.83
Pawnee County	16	9,282	9,092	2.05	8.53
McPherson County	34	4,990	4,652	6.77	9.52
Missouri:					
Saline County	31	2,523	2,362	6.38	13.26
Jasper County	10	2,960	2,949	.37	16.43
St. Charles County	.....	3,035	3,035	.....	.....
Nebraska:					
Phelps County	30	4,573	4,404	3.70	8.46
Saline County	3	2,018	2,008	.50	29.73
Keith County	.....	4,395	4,395	.....	.....
All winter wheat	16	43,940	42,714	2.79	9.18

OVERHEAD.

In addition to items of expense such as labor, seed, twine, thrashing, etc., which are directly chargeable to wheat, there are certain items of general farm expense that are not only an essential part of the wheat account, but also a part of the cost of every other crop and

each kind of live stock produced. This list contains such items as interest and taxes on barn lots, fence rows, roads, etc., building and fence repairs and maintenance, and miscellaneous cash expenses.

It is generally considered that these items of farm expense can be handled best by allowing this miscellaneous cost to represent a certain per cent of the combined material and labor costs of each enterprise. Detailed cost-accounting records as kept on representative wheat farms in several of the areas visited show that this charge amounts to approximately 12 per cent of the value of labor, materials, and thrashing. Since the type of farming in the districts studied is so similar, this rate has been used for all farms.

CREDITS.

The items which have been considered as a credit to the wheat crop are straw, pasture, and special insurance received for damage to the crop through fire or hail. The straw was considered of very little money value and often only that portion needed for bedding was saved; the remainder was left to rot or was burned in stacks in the field.

In the winter-wheat areas some farmers pastured the young wheat during the fall and spring months. This was especially true in Kansas and Missouri. In Saline County, Mo., the high credit for pasture was largely due to a considerable area being so badly lodged that it was not cut, but was pastured with hogs.

In only a few instances was insurance reported as having been received for losses owing to fire or hail. (See Table XXX.)

TABLE XXX.—*Credit per acre, spring and winter wheat—1919 (481 farms).*

State and county.	Straw.	Pasture.	Special crop insurance received.	Total.
North Dakota:				
Grand Forks County	$0.19	.....	.....	$0.19
Morton County	.44	.....	$0.06	.50
South Dakota:				
Spink County	.19	.....	.....	.19
Minnesota:				
Clay County	.58	.....	.....	.58
Traverse County	.30	.....	.....	.30
All spring wheat	.34	.....	.01	.35
Kansas:				
Ford County	.30	$0.38	.03	.71
Pawnee County	.18	.98	.13	1.29
McPherson County	.42	.26	.....	.68
Missouri:				
Saline County	.48	1.79	.....	2.27
Jasper County	.57	.41	.16	1.14
St. Charles County	.49	.02	.....	.51
Nebraska:				
Phelps County	.20	.07	.....	.27
Saline County	.34	.....	.....	.34
Keith County	.14	.....	.12	.26
All winter wheat	.30	.46	.06	.82

ARRAY OF FARMS ACCORDING TO COST PER BUSHEL, BY COUNTIES.

In some counties the variation in cost per bushel was much greater than in others. This is brought out in Table XXXI for spring-wheat farms and in Table XXXII for winter-wheat farms.

Of the 29 spring-wheat farms having a cost of $2 or less, nearly 83 per cent were located in Grand Forks County, N. Dak., and Spink County, S. Dak.

TABLE XXXI.—*Array of farms according to cost per bushel, by counties, spring wheat, 1919 (197 farms).*

Cost group.	North Dakota.		South Dakota.	Minnesota.		Total.	Cumulative per cent of all farms.
	Grand Forks County.	Morton County.	Spink County.	Clay County.	Traverse County.		
Per bushel.	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	
$1.10			1			1	0.5
1.20							.5
1.30	1					1	1.0
1.40							1.0
1.50	1					1	1.5
1.60	1	1	1			3	3.0
1.70	2		1			3	4.5
1.80	1		3			4	6.5
1.90	4		2	1	1	8	10.6
2.00	3	1	3		1	8	14.7
2.10	3		1	3	1	8	18.8
2.20	[a] 5		2	1	2	10	23.9
2.30	4	1	2	1	3	11	29.5
2.40	1		[a] 3	1	5	10	34.6
2.50	1		2	1	3	7	38.2
2.60	4		3	3	3	[a] 13	44.8
2.70	1		3	7	1	12	50.9
2.80		1	1	[a] 1	[a] 5	8	55.0
2.90	1		1	1	3	6	58.1
3.00	1	2	2		2	7	61.7
3.10			1		2	3	63.2
3.20					3	3	64.7
3.30	1	3	1		1	6	67.8
3.40	1	1	1	2		5	70.3
3.50		1		3	2	6	73.4
3.60		1			1	2	74.4
3.70			1	2		3	75.9
3.80		1		3		4	77.9
3.90		3	1		1	5	80.5
4.00							80.5
4.10			1	1		2	81.5
4.20		2		1	1	4	83.5
4.30		[a] 1		1		2	84.5
4.40				3		3	86.0
4.50			2	1		3	87.5
4.60	1	2				3	89.0
4.70		3				3	90.5
4.80							90.5
4.90		1			1	2	91.5
5.00	1			1		2	92.5
5.30		2				2	93.5
5.60		2				2	94.5
5.70		1				1	95.0
6.00		2				2	96.0
6.10	1					1	96.5
6.40		1				1	97.0
8.30		1				1	97.5
8.70		1				1	98.0
10.20		1				1	98.5
10.40		1				1	99.0
12.10		1				1	99.5
14.40		1				1	100.0
Total	39	39	39	38	42	197	

[a] Average cost group.

TABLE XXXII.—*Array of farms according to cost per bushel, by counties, winter wheat 1919 (284 farms).*

Cost group.	Kansas.			Missouri.			Nebraska.			Total.	Cumulative per cent of all farms.
	Ford County.	Pawnee County.	McPherson County.	Saline County.	Jasper County.	St. Charles County.	Phelps County.	Saline County.	Keith County.		
Per bushel.	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	*Farms.*	
$1.00	1	.....	.....	.....	.....	.....	.....	.....	1	2	0.7
1.10	2	1	.....	.....	.....	.....	.....	.....	.....	3	1.8
1.20	1	1	.....	1	.....	1	.....	.....	1	5	3.6
1.30	2	2	.....	.....	.....	1	.....	.....	3	8	6.4
1.40	1	4	.....	.....	1	1	.....	1	2	10	9.9
1.50	1	2	.....	2	5	7	.....	.....	3	20	16.9
1.60	4	a 4	.....	.....	2	4	1	1	a 2	18	23.2
1.70	4	4	1	1	3	a 6	.....	1	3	23	31.3
1.80	a 1	5	1	2	a 3	4	2	1	2	21	38.7
1.90	.....	3	5	6	6	3	3	2	2	a 30	49.3
2.00	2	.....	1	1	6	5	3	4	3	25	58.1
2.10	1	1	3	1	1	4	3	8	.....	22	65.8
2.20	1	2	3	a 1	3	1	(a)	a 4	.....	15	71.1
2.30	1	1	2	3	.....	.....	1	2	.....	10	74.6
2.40	2	.....	a 2	.....	.....	1	4	3	.....	12	78.8
2.50	2	.....	5	.....	.....	.....	4	1	.....	12	83.0
2.60	.....	.....	1	.....	.....	.....	1	3	.....	5	84.8
2.70	2	1	3	3	.....	.....	1	1	.....	11	88.7
2.80	.....	.....	.....	1	.....	.....	3	1	.....	5	90.5
2.90	.....	.....	.....	1	.....	.....	1	1	.....	3	91.6
3.00	.....	.....	1	1	.....	.....	.....	.....	.....	2	92.3
3.10	.....	.....	2	1	.....	.....	.....	.....	1	4	93.7
3.20	1	.....	1	.....	.....	.....	.....	.....	.....	2	94.4
3.30	.....	.....	1	1	.....	.....	.....	.....	.....	2	95.1
3.40	.....	.....	.....	.....	.....	.....	1	.....	.....	1	95.4
3.50	.....	.....	1	.....	.....	.....	1	.....	.....	2	96.1
3.60	.....	1	.....	.....	.....	.....	1	1	.....	3	97.2
3.70	.....	.....	.....	1	.....	.....	.....	.....	.....	1	97.5
3.80	.....	.....	1	.....	.....	.....	.....	.....	.....	1	97.8
3.90	.....	.....	1	.....	.....	.....	.....	.....	.....	1	98.1
4.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	98.1
4.10	.....	.....	.....	1	.....	.....	.....	.....	.....	1	98.4
4.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	98.4
4.30	1	.....	.....	.....	.....	.....	.....	.....	.....	1	98.8
5.10	1	.....	.....	.....	.....	.....	.....	.....	.....	1	99.2
5.20	.....	.....	.....	1	.....	.....	.....	.....	.....	1	99.6
8.20	1	.....	.....	.....	.....	.....	.....	.....	.....	1	100.0
Total.	32	32	35	29	30	38	30	35	23	284	.....

a Average cost group.

Of the 15 farms having costs in excess of $5 per bushel, all but one were in Morton County, N. Dak. This means that nearly 36 per cent of the farmers visited in Morton County produced wheat at a cost above that of all the farmers but one visited in the other four counties. Going still further, it was found that less than 8 per cent of the Morton County farmers produced wheat at a cost of $2.70 and less per bushel, while approximately 82 per cent of the farmers visited in Grand Forks County, 69 per cent in Spink County, and 47 per cent in Clay and Traverse Counties had costs of $2.70 and less per bushel.

In the winter-wheat districts, 14 of the 24 farms with costs of $3 and over appeared in McPherson County, Kans., and Saline County, Mo. Considering the winter-wheat areas as a whole, 58 per cent of the winter-wheat farmers produced wheat at a cost of $2 and less. Yet this percentage was much less in some counties and much greater

in others. The approximate per cent of farmers in each county who grew their wheat at a cost of $2 and less is as follows: Ford County, Kans., 59; Pawnee County, Kans., 81; McPherson County, Kans., 23; Saline County, Mo., 45; Jasper County, Mo., 87; St. Charles County, Mo., 84; Phelps County, Nebr., 30; Saline County, Nebr., 29; and Keith County, Nebr., 96. As a class the winter-wheat farmers visited in 1919 had a better wheat year than did the spring-wheat farmers. In fact, about 80 per cent of the winter-wheat farmers had costs ranging from $1.30 to $2.50 per bushel, whereas but 38 per cent of the spring-wheat farmers had costs within this range.

CUMULATIVE PER CENT OF ACREAGE GROWN AT VARIOUS COSTS PER BUSHEL.

In Tables XXXIII and XXXIV the farms are grouped according to costs per bushel so as to show the per cent of the total wheat acreage that was grown at various costs, by counties. In the spring-wheat areas between 52 and 57 per cent of the total wheat acreage of the 197 farms was grown at a cost not exceeding $2.65 per bushel, or the average for all farms. However, 79.3 per cent of the Grand Forks acreage was grown at $2.60 and less per bushel, whereas but 6.5 per cent of the Morton County acreage came in this class.

In the winter-wheat districts between 50 and 54 per cent of the total acreage was grown at a cost of $1.87 or less per bushel, the average for all farms. This figure varied from 15.8 per cent in Saline County, Nebr., to 84 per cent in Pawnee County, Kans.

Thus in some counties the average cost per bushel for the entire acreage of spring wheat or winter wheat covers a high percentage of acreage grown, while in other counties a very small part of the acreage was grown at the average cost.

TABLE XXXIII.—*Cumulative per cent of total wheat acreage grown at various costs per bushel, by counties, spring wheat, 1919 (197 farms).*

Cost group.	Cumulative per cent of harvested acreage.					
	Grand Forks County, N. Dak.	Morton County, N. Dak.	Spink County, S. Dak.	Clay County, Minn.	Traverse County, Minn.	All farms.
Per bushel.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
$1.10	.....	.....	0.6	.....	.....	0.1
1.20	.....	.....	.6	.....	.....	.1
1.30	3.7	.....	.6	.....	.....	1.0
1.40	3.7	.....	.6	.....	.....	1.0
1.50	6.5	.....	.6	.....	.....	1.7
1.60	10.0	0.6	5.3	.....	.....	3.6
1.70	12.6	.6	7.7	.....	.....	4.7
1.80	18.1	.6	21.5	.....	.....	9.1
1.90	26.9	.6	27.8	0.8	1.7	13.0
2.00	32.8	1.7	32.6	.8	2.3	15.7
2.10	43.2	1.7	33.2	5.9	3.7	19.8
2.20	51.4	1.7	39.5	7.1	7.8	24.1
2.30	63.4	6.5	42.1	27.1	17.4	34.6
2.40	64.9	6.5	51.6	28.4	26.7	38.9
2.50	66.5	6.5	56.9	31.5	31.9	42.0
2.60	79.3	6.5	63.1	48.7	40.8	52.0
[a] 2.65	.....	.....	.....	.....	.....	.....
2.70	80.3	6.5	69.3	59.4	45.0	56.9
2.80	80.3	7.2	70.4	61.7	57.4	59.8
2.90	85.9	7.2	72.5	64.6	65.1	63.5
3.00	88.5	10.9	75.4	64.6	68.7	65.8
3.10	88.5	10.9	77.6	64.6	74.7	67.3
3.20	88.5	10.9	77.6	64.6	81.8	68.5
3.30	90.4	24.1	83.1	64.6	82.7	72.1
3.40	93.4	32.2	86.5	66.4	82.7	75.1
3.50	93.4	35.8	86.5	75.2	88.4	78.7
3.60	93.4	40.3	86.5	75.2	91.4	79.8
3.70	93.4	40.3	88.3	77.9	91.4	80.8
3.80	93.4	41.5	88.3	87.6	91.4	83.3
3.90	93.4	44.8	90.0	87.6	94.2	84.6
4.00	93.4	44.8	90.0	87.6	94.2	84.6
4.10	93.4	44.8	93.4	88.3	94.2	85.5
4.20	93.4	48.0	93.4	88.8	99.3	86.9
4.30	93.4	49.7	93.4	90.5	99.3	87.6
4.40	93.4	49.7	93.4	96.6	99.3	89.1
4.50	93.4	49.7	100.0	97.9	99.3	90.9
4.60	94.9	54.0	.....	97.9	99.3	91.9
4.70	94.9	62.6	.....	97.9	99.3	93.1
4.80	94.9	62.6	.....	97.9	99.3	93.1
4.90	94.9	64.3	.....	97.9	100.0	93.5
5.00	95.5	64.3	.....	100.0	.....	94.1
5.30	95.5	69.6	.....	.....	.....	94.8
5.60	95.5	73.8	.....	.....	.....	95.4
5.70	95.5	76.7	.....	.....	.....	95.8
6.00	95.5	83.8	.....	.....	.....	96.8
6.10	100.0	83.8	.....	.....	.....	97.8
6.40	.....	87.7	.....	.....	.....	98.3
8.30	.....	88.7	.....	.....	.....	98.4
8.70	.....	89.4	.....	.....	.....	98.5
10.20	.....	90.8	.....	.....	.....	98.7
10.40	.....	94.3	.....	.....	.....	99.2
12.10	.....	95.7	.....	.....	.....	99.4
14.40	.....	100.0	.....	.....	.....	100.0

[a] Average cost per bushel for all spring wheat.

TABLE XXXIV.—*Cumulative per cent of total wheat acreage grown at various costs per bushel, by counties, winter wheat, 1919 (284 farms).*

Cost group.	Cumulative per cent of harvested acreage.									
	Ford County, Kans.	Pawnee County, Kans.	McPherson County, Kans.	Saline County, Mo.	Jasper County, Mo.	St. Charles County, Mo.	Phelps County, Nebr.	Saline County, Nebr.	Keith County, Nebr.	All farms.
Per bush.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
$1.00	3.3	.....	.....	.....	.....	.....	.....	.....	10.2	1.8
1.10	7.5	5.2	.....	.....	.....	.....	.....	.....	10.2	3.9
1.20	8.5	6.7	.....	3.8	.....	3.0	.....	.....	11.7	5.0
1.30	16.6	10.8	.....	3.8	.....	7.7	.....	.....	22.1	9.1
1.40	20.4	23.1	.....	3.8	4.9	10.9	.....	2.5	30.1	14.1
1.50	24.3	29.7	.....	7.0	18.7	28.5	.....	2.5	50.6	20.9
1.60	34.7	41.3	.....	7.0	22.4	38.8	2.7	5.2	54.4	27.6
1.70	43.9	63.5	1.4	11.2	36.0	51.8	2.7	6.7	60.0	37.3
1.80	47.1	77.0	2.8	25.0	50.6	60.7	9.2	9.1	67.7	45.0
[a] 1.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.90	47.1	84.2	16.1	45.9	72.1	68.2	24.5	15.8	78.8	54.2
2.00	55.3	84.2	19.8	48.9	92.5	79.8	44.9	27.0	99.6	63.6
2.10	59.8	86.8	26.0	51.2	95.0	89.8	53.9	47.3	99.6	68.8
2.20	62.2	92.8	34.7	54.8	100.0	92.4	53.9	60.9	99.6	72.9
2.30	66.5	95.5	44.8	67.9	.....	92.4	57.3	66.4	99.6	76.9
2.40	71.1	95.5	50.9	67.9	.....	100.0	67.0	78.5	99.6	80.7
2.50	76.9	95.5	68.9	67.9	.....	.....	77.1	81.7	99.6	85.2
2.60	76.9	95.5	73.2	67.9	.....	.....	80.0	92.2	99.6	86.5
2.70	87.8	97.7	81.6	77.2	.....	.....	82.7	94.0	99.6	91.3
2.80	87.8	97.7	81.6	80.0	.....	.....	87.5	95.0	99.6	92.0
2.90	87.8	97.7	81.6	87.4	.....	.....	89.3	97.5	99.6	92.7
3.00	87.8	97.7	84.7	89.0	.....	.....	89.3	97.5	99.6	93.1
3.10	87.8	97.7	89.9	90.3	.....	.....	89.3	97.5	100.0	93.8
3.20	90.9	97.7	92.5	90.3	.....	.....	89.3	97.5	.....	94.8
3.30	90.9	97.7	93.0	93.0	.....	.....	89.3	97.5	.....	95.0
3.40	90.9	97.7	93.0	93.0	.....	.....	93.9	97.5	.....	95.5
3.50	90.9	97.7	94.3	93.0	.....	.....	96.6	97.5	.....	95.9
3.60	90.9	100.0	94.3	93.0	.....	.....	100.0	100.0	.....	96.9
3.70	90.9	.....	94.3	96.2	.....	.....	.....	.....	.....	97.1
3.80	90.9	.....	96.1	96.2	.....	.....	.....	.....	.....	97.3
3.90	90.9	.....	100.0	96.2	.....	.....	.....	.....	.....	97.7
4.00	90.9	.....	.....	96.2	.....	.....	.....	.....	.....	97.7
4.10	90.9	.....	.....	98.3	.....	.....	.....	.....	.....	97.8
4.20	90.9	.....	.....	98.3	.....	.....	.....	.....	.....	97.8
4.30	93.4	.....	.....	98.3	.....	.....	.....	.....	.....	98.4
5.10	96.5	.....	.....	.....	.....	.....	.....	.....	.....	99.1
5.20	.....	.....	.....	100.0	.....	.....	.....	.....	.....	99.2
8.20	100.0	.....	.....	.....	.....	.....	.....	.....	.....	100.0

[a] Average cost per bushel for all winter wheat.

CUMULATIVE PER CENT OF TOTAL PRODUCTION.

Tables XXXV and XXXVI show the cumulative per cent of total production with reference to cost per bushel.

In the spring-wheat areas about 67 per cent of the total bushels harvested was grown on farms havings costs not in excess of the general average of $2.65 per bushel. This percentage varied in different counties. In Grand Forks County, 87 per cent of the production was grown at a cost of $2.60 or less, but in Morton County only 13.3 per cent was produced as cheaply as $2.60 per bushel.

In the winter-wheat districts approximately 60 per cent of the total production was raised at the average cost or less per bushel. As in the spring-wheat districts, the cumulative per cent of production grown at various costs per bushel showed considerable variation among the various districts visited.

TABLE XXXV.—*Cumulative per cent of total production, by counties, spring wheat, 1919 (197 farms).*

Cost group.	Cumulative per cent of production.					
	Grand Forks County, N. Dak.	Morton County, N. Dak.	Spink County, S. Dak.	Clay County, Minn.	Traverse County, Minn.	All farms.
Per bushel.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
$1.10	.....	.....	1.3	.....	.....	0.3
1.20	.....	.....	1.3	.....	.....	.3
1.30	5.9	.....	1.3	.....	.....	1.9
1.40	5.9	.....	1.3	.....	.....	1.9
1.50	10.7	.....	1.3	.....	.....	3.2
1.60	15.0	1.2	8.6	.....	.....	6.4
1.70	17.9	1.2	12.1	.....	.....	8.1
1.80	24.6	1.2	31.4	.....	.....	14.9
1.90	35.4	1.2	39.2	1.6	2.3	20.6
2.00	42.9	2.9	45.1	1.6	3.3	24.5
2.10	54.7	2.9	45.9	8.8	4.9	29.8
2.20	62.4	2.9	52.6	10.6	10.3	34.9
2.30	74.4	13.3	55.3	35.6	20.4	47.1
2.40	76.1	13.3	62.5	37.3	30.9	51.5
2.50	77.6	13.3	67.2	40.7	37.0	54.9
2.60	86.9	13.3	72.3	57.8	46.4	64.3
[a] 2.65	.....	.....	.....	.....	.....	.....
2.70	88.1	13.3	77.6	69.5	50.1	69.3
2.80	88.1	14.1	78.5	71.9	63.1	72.3
2.90	91.8	14.1	79.7	74.7	71.1	75.6
3.00	93.8	19.0	82.1	74.7	74.6	77.7
3.10	93.8	19.0	84.3	74.7	79.7	79.1
3.20	93.8	19.0	84.3	74.7	85.9	80.1
3.30	94.9	33.2	89.2	74.7	86.8	82.8
3.40	96.7	43.4	91.8	76.6	86.8	85.1
3.50	96.7	47.3	91.8	82.8	91.5	87.6
3.60	96.7	53.4	91.8	82.8	94.0	88.5
3.70	96.7	53.4	92.9	84.7	94.0	89.2
3.80	96.7	54.4	92.9	91.5	94.0	90.9
3.90	96.7	58.5	93.9	91.5	95.5	91.7
4.00	96.7	58.5	93.9	91.5	95.5	91.7
4.10	96.7	58.5	96.2	92.0	95.5	92.4
4.20	96.7	61.9	96.2	92.4	99.2	93.3
4.30	96.7	63.8	96.2	93.9	99.2	93.8
4.40	96.7	63.8	96.2	97.7	99.2	94.7
4.50	96.7	63.8	100.0	98.6	99.2	95.9
4.60	97.5	67.7	.....	98.6	99.2	96.4
4.70	97.5	73.9	.....	98.6	99.2	96.8
4.80	97.5	73.9	.....	98.6	99.2	96.8
4.90	97.5	75.7	.....	98.6	100.0	97.1
5.00	97.9	75.7	.....	100.0	.....	97.5
5.30	97.9	81.5	.....	.....	.....	97.9
5.60	97.9	84.4	.....	.....	.....	98.1
5.70	97.9	87.6	.....	.....	.....	98.3
6.00	97.9	92.7	.....	.....	.....	98.7
6.10	100.0	92.7	.....	.....	.....	99.2
6.40	.....	95.3	.....	.....	.....	99.4
8.30	.....	96.1	.....	.....	.....	99.5
8.70	.....	96.6	.....	.....	.....	99.6
10.20	.....	97.4	.....	.....	.....	99.7
10.40	.....	98.6	.....	.....	.....	99.8
12.10	.....	99.1	.....	.....	.....	99.9
14.40	.....	100.0	.....	.....	.....	100.0

[a] Average cost per bushel for all spring wheat.

TABLE XXXVI.—*Cumulative per cent of total production, by counties, winter wheat, 1919 (284 farms).*

Cost group.	Cumulative per cent of total production.									
	Ford County, Kans.	Pawnee County, Kans.	McPherson County, Kans.	Saline County, Mo.	Jasper County, Mo.	St. Charles County, Mo.	Phelps County, Nebr.	Saline County, Nebr.	Keith County, Nebr.	All farms.
Per bush.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
$1.00	4.2	.....	.....	.....	.....	.....	.....	.....	11.3	2.3
1.10	11.3	6.9	.....	.....	.....	.....	.....	.....	11.3	5.1
1.20	12.8	7.8	.....	4.6	.....	3.6	.....	.....	13.4	6.5
1.30	24.9	12.9	.....	4.6	.....	9.1	.....	.....	25.1	12.0
1.40	31.1	28.5	.....	4.6	5.2	12.5	.....	3.0	34.5	18.5
1.50	37.2	35.9	.....	9.0	20.4	33.6	.....	3.0	55.6	27.5
1.60	52.1	48.5	.....	9.0	24.1	43.6	4.3	6.4	58.6	35.2
1.70	61.0	69.2	1.8	15.2	38.3	56.8	4.3	8.3	64.9	45.1
1.80	64.6	82.7	3.8	31.4	53.3	65.7	11.4	11.0	72.8	53.6
1.87[a]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.90	64.6	89.7	22.1	54.9	74.0	73.8	30.4	18.6	83.5	63.9
2.00	74.5	89.7	25.7	58.2	92.9	85.0	54.1	30.6	99.8	73.7
2.10	77.3	91.7	31.8	60.6	95.4	93 0	64.5	51.8	99.8	78.4
2.20	78.9	96.3	41.2	65.4	100.0	95.0	64.5	66.0	99.8	82.2
2.30	82.9	97.9	52.1	75.5	.....	95.0	68.0	71.5	99.8	85.5
2.40	86.3	97.9	58.2	75.5	.....	100.0	76.4	82.2	99.8	88.5
2.50	90.4	97.9	76.1	75.5	.....	.....	84.8	85.2	99.8	91.8
2.60	90.4	97.9	80.8	75.5	.....	.....	86.7	94.5	99.8	92.9
2.70	96.8	99.2	88.0	84.3	.....	.....	89.1	95.9	99.8	95.9
2.80	96.8	99.2	88.0	86.2	.....	.....	93.1	96.7	99.8	96.4
2.90	96.8	99.2	88.0	92.6	.....	.....	94.4	98.6	99.8	97.0
3.00	96.8	99.2	90.4	93.6	.....	.....	94.4	98.6	99.8	97.3
3.10	96.8	99.2	94.1	94.5	.....	.....	94.4	98.6	100.0	97.7
3.20	98.1	99.2	95.5	94.5	.....	.....	94.4	98.6	.....	98.1
3.30	98.1	99.2	96.0	96.7	.....	.....	94.4	98.6	.....	98.3
3.40	98.1	99.2	96.0	96.7	.....	.....	97.0	98.6	.....	98.5
3.50	98.1	99.2	96.9	96.7	.....	.....	98.4	98.6	.....	98.7
3.60	98.1	100.0	96.9	96.7	.....	.....	100.0	100.0	.....	99.1
3.70	98.1	.....	96.9	98.2	.....	.....	.....	.....	.....	99.2
3.80	98.1	.....	97.9	98.2	.....	.....	.....	.....	.....	99.3
3.90	98.1	.....	100.0	98.2	.....	.....	.....	.....	.....	99.5
4.00	98.1	.....	.....	98.2	.....	.....	.....	.....	.....	99.5
4.10	98.1	.....	.....	99.2	.....	.....	.....	.....	.....	99.6
4.20	98.1	.....	.....	.....	.....	.....	.....	.....	.....	99.6
4.30	98.7	.....	.....	.....	.....	.....	.....	.....	.....	99.7
5.10	99.4	.....	.....	.....	.....	.....	.....	.....	.....	99.8
5.20	.....	.....	.....	100.0	.....	.....	.....	.....	.....	99.9
8.20	100.0	.....	.....	.....	.....	.....	.....	.....	.....	100.0

[a] Average cost per bushel for all winter wheat.

INDIVIDUAL COSTS PER ACRE.

Table XXXVII shows costs per acre for each of the owned farms covered by the survey.

TABLE XXXVII.—*Individual costs per acre on owned land, spring and winter wheat, 1919 (327 farms).*

Record number.	Acres harvested.	Factors of cost, per acre.								Total net cost, with rent.		Yield per acre.
		Labor.	Material.	Thrashing.	Miscellaneous.	Total gross cost, without rent.	Credit.	Total net cost, without rent.	Rent (interest on investment).	Per acre.	Per bushel.	
						SPRING WHEAT.						
						GRAND FORKS COUNTY, N. DAK.						
1	375	$6.25	$3.59	$2.72	$3.22	$15.78	.....	$15.78	$3.60	$19.38	$1.26	15.4
2	280	7.43	4.63	3.21	5.12	20.39	$0.36	20.03	5.40	25.43	1.52	16.7
3	260	3.63	3.60	2.88	3.92	14.03	.50	13.53	6.00	19.53	1.63	12.0
4	173	6.59	4.67	3.58	3.95	18.79	.....	18.79	3.60	22.39	1.64	13.7
5	200	5.42	3.47	3.67	3.29	15.85	.....	15.85	2.40	18.25	1.66	11.0
6	180	8.88	4.66	3.19	4.66	21.39	.....	21.39	4.50	25.89	1.71	11.9
7	65	4.84	3.94	2.12	3.08	13.98	.46	13.52	5.40	18.92	1.72	11.0
8	63	9.37	3.94	4.00	4.86	22.17	.63	21.54	4.50	26.04	1.75	14.9
9	553	7.02	4.27	2.25	3.50	17.04	.09	16.95	4.20	21.15	1.76	12.0
10	475	5.66	3.80	3.18	3.40	16.04	.....	16.04	6.00	22.04	1.87	11.8
11	236	8.07	4.26	3.18	4.76	20.27	.21	20.06	4.50	24.56	1.88	13.1
12	110	6.53	3.99	2.24	3.35	16.11	.....	16.11	5.40	21.51	1.89	11.4
13	65	7.54	4.10	2.07	4.46	18.17	.77	17.40	4.20	21.60	1.92	11.3
14	200	5.58	4.15	3.92	5.22	18.87	.17	18.70	3.30	22.00	1.95	11.3
15	80	5.83	3.19	1.75	3.34	14.11	.....	14.11	5.40	19.51	2.08	9.4
16	410	5.55	2.81	3.66	4.40	16.42	.....	16.42	5.40	21.82	2.14	10.2
17	90	6.30	3.28	2.78	3.97	16.33	.....	16.33	5.40	21.73	2.24	9.7
18	300	8.06	4.01	4.77	5.20	22.04	.17	21.87	5.10	26.97	2.34	11.5
61	295	5.37	4.47	1.87	3.44	15.15	.30	14.85	5.10	19.95	2.67	7.5
20	160	6.61	3.76	2.25	3.73	16.35	.....	16.35	7.50	23.85	2.98	8.0
21	300	6.25	4.22	2.50	4.44	17.41	.20	17.21	3.00	20.21	3.37	6.0
22	15	6.63	4.19	3.82	3.53	18.17	2.33	15.84	3.60	19.44	3.89	5.0
23	155	7.69	4.63	2.58	5.40	20.30	.32	19.98	3.60	23.58	4.57	5.2
24	450	5.46	4.57	2.22	10.18	22.43	.89	21.54	6.00	27.54	6.12	4.5
						MORTON COUNTY, N. DAK.						
1	35	$6.13	$2.84	$0.81	$3.11	$12.89	$1.14	$11.75	$2.40	$14.15	$1.64	8.6
2	63	6.33	2.05	.59	3.76	12.73	.71	12.02	2.10	14.12	2.03	6.9
3	12	5.51	3.15	.66	3.12	12.44	1.50	10.94	3.00	13.94	2.29	6.1
4	280	10.58	3.83	.93	4.27	19.61	.18	19.43	2.70	22.13	2.29	9.6
5	40	8.22	2.52	.50	3.36	14.60	2.50	12.10	1.80	13.90	2.78	5.0
6	65	11.41	3.68	.64	4.54	20.27	.77	19.50	2.10	21.60	2.99	7.2
7	150	7.23	2.71	.57	4.07	14.58	.53	14.05	2.10	16.15	3.04	5.3
8	275	8.03	3.54	.83	6.45	18.85	.25	18.60	2.10	20.70	3.06	6.8
9	500	4.13	3.14	.33	2.86	10.46	.20	10.26	3.00	13.26	3.19	4.2
10	50	9.65	4.28	.60	9.95	24.48	.....	24.48	2.10	26.58	3.32	8.0
11	210	8.99	3.11	.37	3.23	15.70	.31	15.39	1.50	16.89	3.50	4.8
12	260	11.68	3.18	.65	5.00	20.51	.77	19.74	1.80	21.54	3.57	6.0
13	30	9.63	2.92	.64	3.35	16.54	.30	16.24	1.20	17.44	3.74	4.7
14	25	11.64	3.14	.69	6.49	21.96	.28	21.68	1.80	23.48	3.86	6.1
15	120	10.28	4.19	.48	4.68	19.63	1.25	18.38	3.60	21.98	3.92	5.6
16	140	5.54	3.15	.30	4.02	13.01	.27	12.74	1.80	14.54	4.11	3.5
17	40	9.38	3.43	.53	5.04	18.38	.60	17.78	2.40	20.18	4.12	4.9
18	100	8.95	3.38	.46	4.21	17.00	.50	16.50	1.50	18.00	4.23	4.3
19	100	9.34	3.13	.52	5.47	18.46	.75	17.71	3.60	21.31	4.30	5.0
20	150	8.59	4.24	.30	3.27	16.40	.50	15.90	2.40	18.30	4.58	4.0
21	100	8.95	3.34	.36	4.67	17.32	.45	16.87	1.80	18.67	4.60	4.1
22	100	12.09	2.32	.50	5.25	20.16	.18	19.98	1.80	21.78	4.74	4.6
23	100	10.62	3.59	.53	7.41	22.15	1.08	21.07	2.10	23.17	4.88	4.8
24	150	8.79	3.01	.37	15.03	27.20	.80	26.40	1.50	27.90	5.28	5.3
25	160	13.14	3.14	.46	4.79	21.53	.19	21.34	1.50	22.84	5.33	4.3
26	60	7.98	2.52	.25	2.85	13.60	.20	13.40	2.10	15.50	5.57	2.8
27	186	8.07	3.46	.25	4.81	16.59	.67	15.92	2.10	18.02	5.64	3.2
28	170	10.45	4.01	.52	12.36	27.34	1.47	25.87	2.10	27.97	5.68	4.9

TABLE XXXVII.—*Individual costs per acre on owned land, spring and winter wheat, 1919 (327 farms)*—Continued.

Record number.	Acres harvested.	Factors of cost, per acre.								Total net cost, with rent.		Yield per acre.
		Labor.	Material.	Thrashing.	Miscellaneous.	Total gross cost, without rent.	Credit.	Total net cost, without rent.	Rent (interest on investment).	Per acre.	Per bushel.	
						SPRING WHEAT—Coctinued.						
						MORTON COUNTY, N. DAK.—Continued.						
29	140	$9.31	$3.17	$0.27	$4.82	$17.57	$2.32	$15.25	$2.40	$17.65	$5.98	3.0
30	275	10.75	2.26	.35	5.02	18.38	.45	17.93	2.10	20.03	6.03	3.3
31	100	8.78	4.20	.28	4.04	17.30	.33	16.97	3.00	19.97	6.79	2.9
32	23	6.19	2.70	.18	4.56	13.63	.22	13.41	1.50	14.91	7.45	2.0
33	60	8.79	3.23	.36	16.39	28.77	.83	27.94	1.80	29.74	8.30	3.6
34	80	14.62	4.40	.24	4.74	24.00	.32	23.68	1.50	25.18	10.17	2.5
35	205	7.44	3.28	.24	3.37	14.33	.15	14.18	1.50	15.68	10.44	1.5
36	80	8.55	2.43	.20	7.20	18.38	.75	17.63	3.00	20.63	12.13	1.7
37	250	6.38	3.01	.10	3.01	12.50	.20	12.30	1.50	13.80	14.38	1.0
						SPINK COUNTY, S. DAK.						
1	60	$5.82	$3.14	$5.00	$4.30	$18.26	$0.42	$17.84	$6.00	$23.84	$1.15	20.8
2	120	5.97	4.03	3.53	3.33	16.86	.....	16.86	6.00	22.86	1.39	16.4
3	60	8.96	3.89	1.11	4.77	18.73	2.25	16.48	6.00	22.48	1.79	12.6
4	135	5.44	3.97	2.95	4.04	16.40	.30	16.10	6.00	22.10	2.01	11.0
5	145	6.73	2.20	3.49	3.65	16.07	.25	15.82	8.10	23.92	2.03	11.8
6	180	8.11	3.13	3.58	4.31	19.13	.05	19.08	7.50	26.58	2.03	13.1
7	60	10.52	3.69	1.35	4.14	19.70	.....	19.70	7.50	27.20	2.15	12.7
8	100	4.17	2.99	2.08	4.09	13.33	.....	13.33	6.00	19.33	2.18	8.8
9	200	8.18	3.73	2.73	4.22	18.86	.25	18.61	7.50	26.11	2.25	11.6
10	85	6.97	3.10	3.18	4.89	18.14	.59	17.55	9.60	27.15	2.30	11.8
11	163	7.46	3.80	3.04	3.74	18.04	.61	17.43	6.00	23.43	2.39	9.8
12	250	6.79	3.05	2.97	4.54	17.35	.....	17.35	9.00	26.35	2.48	10.6
13	85	4.78	3.46	1.91	4.18	14.33	.....	14.33	6.00	20.33	2.63	7.7
14	300	5.56	3.43	2.59	4.17	15.75	.33	15.42	9.00	24.42	2.66	9.2
15	100	6.20	2.58	2.92	3.85	15.55	.50	15.05	6.00	21.05	2.68	7.8
16	190	6.68	4.19	1.64	3.17	15.68	.53	15.15	6.00	21.15	2.71	7.8
17	100	4.71	3.04	3.10	4.52	15.37	.25	15.12	9.00	24.12	2.82	8.6
18	75	10.14	5.42	2.35	5.79	23.70	.....	23.70	9.00	32.70	3.03	10.8
19	210	7.64	4.08	2.55	4.41	18.68	.....	18.68	12.00	30.68	3.10	9.9
20	40	8.39	2.98	2.24	3.70	17.31	.....	17.31	5.40	22.71	3.13	7.2
21	100	7.44	3.01	2.36	3.91	16.72	.12	16.60	6.00	22.60	3.30	6.8
22	525	8.26	3.61	4.69	3.74	20.30	.05	20.25	9.00	29.25	3.35	7.8
23	320	6.07	3.04	2.28	5.50	16.89	.47	16.42	9.60	26.02	3.42	7.6
24	160	5.59	3.31	1.97	6.68	17.55	.....	17.55	6.00	23.55	3.90	6.0
25	120	8.40	3.26	1.08	3.54	16.28	.50	15.78	7.50	23.28	3.98	5.8
26	320	8.06	3.29	1.78	3.94	17.07	.25	16.82	10.50	27.32	4.11	6.6
27	300	11.94	3.48	1.16	4.20	20.78	.33	20.45	7.50	27.95	4.49	6.2
28	330	5.76	3.31	3.28	3.50	15.85	.25	15.60	7.50	23.10	4.54	5.1
						CLAY COUNTY, MINN.						
1	58	$6.89	$4.45	$0.96	$3.78	$16.08	$0.26	$15.82	$7.50	$23.32	$1.54	15.1
2	80	9.86	5.18	3.45	5.76	24.25	.31	23.94	7.50	31.44	1.90	16.6
3	160	9.46	5.50	1.76	4.80	21.52	.13	21.39	6.00	27.39	2.08	13.2
4	127	8.09	3.72	1.16	4.48	17.45	.....	17.45	9.00	26.45	2.19	12.1
5	85	5.84	3.66	1.10	4.32	14.92	.16	14.76	6.00	20.76	2.42	8.6
6	35	5.32	3.81	.92	4.15	14.20	.11	14.09	12.00	26.09	2.47	10.6
7	900	5.68	4.25	.85	3.35	14.13	1.39	12.74	9.00	21.74	2.62	8.3
8	120	10.02	5.82	1.56	6.14	23.54	.21	23.33	9.00	32.33	2.69	12.0
9	110	9.19	4.27	1.46	4.47	19.39	.45	18.94	12.00	30.94	2.71	11.4
10	930	4.64	4.64	1.20	6.41	16.89	.48	16.41	12.00	28.41	2.80	10.2
11	240	7.82	3.95	1.25	3.98	17.00	.42	16.58	6.60	23.18	2.81	8.2
12	300	9.36	3.74	.97	3.55	17.62	.17	17.45	6.00	23.45	2.93	8.0
13	90	10.30	4.60	1.27	4.53	20.70	.56	20.14	6.00	26.14	3.36	7.8
14	100	12.81	4.91	1.74	6.34	25.80	.50	25.30	6.00	31.30	3.43	9.1
15	280	6.13	4.36	.79	6.74	18.02	.23	17.79	6.60	24.39	3.48	7.0
16	160	4.36	4.99	.74	6.07	16.16	1.25	14.91	9.00	23.91	3.71	6.4
17	75	8.81	4.58	1.91	4.66	19.96	1.04	18.92	10.50	29.42	3.79	7.8
18	800	8.47	3.67	1.36	3.05	16.55	156	14.99	6.00	20.99	3.83	5.5

TABLE XXXVII.—*Individual costs per acre on owned land, spring and winter wheat, 1919 (327 farms)*—Continued.

Record number.	Acres harvested.	Factors of cost, per acre.								Total net cost, with rent.		Yield per acre.
		Labor.	Material.	Thrashing.	Miscellaneous.	Total gross cost, without rent.	Credit.	Total net cost, without rent.	Rent (interest on investment).	Per acre.	Per bushel.	
						SPRING WHEAT—Continued.						
						CLAY COUNTY, MINN.—Continued.						
19	70	$8.71	$5.41	$0.94	$3.95	$19.01	.....	$19.01	$7.50	$26.51	$4.08	6.5
20	100	8.97	4.07	.93	3.82	17.79	$0.16	17.63	6.00	23.63	4.30	5.5
21	180	11.34	4.24	2.41	6.76	24.75	1.11	23.64	7.50	31.14	4.32	7.2
22	250	10.50	3.90	2.43	3.85	20.68	.20	20.48	6.00	26.48	4.41	6.0
23	130	11.47	6.29	1.43	5.94	25.13	3.08	22.05	7.50	29.55	4.49	6.6
24	220	7.08	3.82	.48	6.38	17.76	.68	17.08	9.00	26.08	5.02	5.2
25	30	7.73	4.48	1.56	3.72	17.49	.....	17.49	9.00	26.49	5.30	5.0
26	75	8.12	4.07	1.25	5.31	18.75	.44	18.31	6.00	24.31	6.68	3.6
						TRAVERSE COUNTY, MINN.						
1	120	$8.63	$3.48	$1.48	$3.27	$16.86	$0.34	$16.52	$4.80	$21.32	$1.91	11.2
2	97	8.46	3.33	1.29	4.69	17.77	.32	17.45	9.00	26.45	2.02	13.1
3	45	9.99	4.99	1.45	5.08	21.51	.....	21.51	5.40	26.91	2.05	13.1
4	100	8.68	4.40	1.30	3.02	17.40	1.60	15.80	4.80	20.60	2.10	9.8
5	70	10.77	4.02	1.41	4.23	20.43	.....	20.43	6.00	26.43	2.22	11.9
6	160	8.13	4.76	1.44	4.34	18.67	.94	17.73	7.50	25.23	2.24	11.2
7	30	7.80	4.02	1.04	2.94	15.80	.27	15.53	6.00	21.53	2.27	9.5
8	500	7.99	3.71	.97	2.98	15.65	.30	15.35	4.80	20.15	2.28	8.8
9	70	7.99	4.29	1.60	3.84	17.72	.36	17.36	6.00	23.36	2.31	10.1
10	275	5.11	4.01	.75	5.29	15.16	.45	14.71	6.00	20.71	2.40	8.6
11	33	10.59	4.04	2.45	4.35	21.43	.45	20.98	12.00	32.98	2.44	13.6
12	90	8.86	3.92	.93	5.27	18.98	.20	18.78	7.50	26.28	2.44	10.8
13	100	12.29	4.38	1.57	5.04	23.28	.13	23.15	6.00	29.15	2.50	11.6
14	160	10.18	4.45	1.47	4.46	20.56	.50	20.06	7.80	27.86	2.53	11.0
15	230	8.20	4.47	.90	2.84	16.41	.05	16.36	4.80	21.16	2.61	8.1
16	300	5.90	3.18	.96	4.67	14.71	.67	14.04	6.00	20.04	2.73	7.4
17	50	8.09	4.14	.97	3.57	16.77	.66	16.11	7.50	23.61	2.75	8.6
18	340	10.96	3.48	1.48	3.97	19.89	.15	19.74	7.20	26.94	2.78	9.7
19	165	5.61	3.56	1.13	5.28	15.58	.30	15.28	7.50	22.78	2.78	8.2
20	70	9.86	4.12	.88	3.47	18.33	1.00	17.33	6.00	23.33	2.79	8.4
21	160	9.35	3.55	.98	4.11	17.99	.....	17.99	6.00	23.99	2.79	8.6
22	90	11.23	4.63	1.07	4.21	21.14	.39	20.75	7.20	27.95	2.85	9.8
23	40	8.32	3.97	1.66	3.71	17.66	.....	17.66	6.00	23.66	2.86	8.3
24	200	10.87	3.70	1.69	4.00	20.26	.25	20.01	4.80	24.81	2.93	8.5
25	200	8.78	4.42	1.13	3.69	18.02	.10	17.92	7.50	25.42	2.94	8.6
26	155	8.77	4.53	1.70	3.50	18.50	.....	18.50	9.00	27.50	2.99	9.2
27	225	9.57	3.35	.71	3.61	17.24	.....	17.24	6.00	23.24	3.06	7.6
28	230	11.17	4.14	1.17	3.78	20.26	.22	20.04	6.00	26.04	3.18	8.2
29	40	10.83	3.29	2.65	4.03	20.80	.27	20.53	6.00	26.53	3.22	8.2
30	60	12.68	4.04	1.43	4.91	23.06	.42	22.64	7.50	30.14	3.29	9.2
31	100	9.29	4.29	.93	4.13	18.64	1.00	17.64	9.00	26.64	3.46	7.7
32	300	8.25	4.45	.77	2.97	16.44	.....	16.44	7.50	23.94	3.54	6.0
33	210	11.04	4.13	.80	4.29	20.26	.....	20.26	4.80	25.06	3.58	7.0
34	90	8.03	4.50	1.14	3.16	16.83	.50	16.33	6.00	22.33	3.59	6.2
35	360	8.80	4.40	1.22	4.14	18.56	.....	18.56	7.50	26.06	4.24	6.2
36	51	17.73	5.77	2.94	9.65	36.09	.25	35.84	12.00	47.84	4.93	9.7
						WINTER WHEAT.						
						FORD COUNTY, KANS.						
1	320	$9.29	$2.06	$0.42	$2.48	$14.25	$0.84	$13.41	$3.60	$17.01	$0.98	17.4
2	90	10.30	1.85	4.48	5.08	21.71	2.90	18.81	3.00	21.81	.99	22.0
3	200	13.43	2.68	4.59	5.16	25.86	3.60	22.26	3.60	25.86	1.06	24.3
4	300	8.95	2.53	4.45	5.39	21.32	.54	20.78	4.50	25.28	1.15	22.0
5	220	10.41	2.35	4.00	4.37	21.13	1.73	19.40	3.60	23.00	1.15	20.0
6	100	9.79	2.88	3.49	5.85	22.01	1.20	20.81	3.00	23.81	1.24	19.2
7	335	9.94	2.24	3.10	4.60	19.88	.36	19.52	3.00	22.52	1.26	17.9
8	240	11.15	2.73	4.44	5.65	23.97	.....	23.97	4.50	28.47	1.29	22.0
9	190	7.50	1.65	2.20	4.53	15.88	.31	15.57	3.00	18.57	1.29	14.4
10	190	8.87	1.72	3.92	3.37	17.88	.05	17.83	2.40	20.23	1.29	15.7
11	110	9.72	1.64	3.86	5.76	20.98	1.56	19.42	3.00	22.42	1.34	16.8

TABLE XXXVII.—*Individual costs per acre on owned land, spring and winter wheat, 1919 (327 farms)*—Continued.

Record number.	Acres harvested.	Factors of cost, per acre.								Total net cost, with rent.		Yield per acre.
		Labor.	Material.	Thrashing.	Miscellaneous.	Total gross cost, without rent.	Credit.	Total net cost, without rent.	Rent (interest on investment).	Per acre.	Per bushel.	
					WINTER WHEAT—Continued.							
					FORD COUNTY, KANS.—Continued.							
12	100	$9.41	$1.36	$2.85	$2.44	$16.06	$0.34	$15.72	$2.40	$18.12	$1.41	12.9
13	80	12.35	2.01	2.90	5.36	22.62	2.37	20.25	3.00	23.25	1.55	15.0
14	230	11.89	2.73	3.46	6.23	24.31	.09	24.22	3.00	27.22	1.60	17.0
15	175	11.41	1.73	2.65	4.53	20.32	.20	20.12	3.00	23.12	1.69	13.7
16	105	7.72	2.43	2.10	5.11	17.36	.69	16.67	3.00	19.67	1.90	10.4
17	140	8.48	1.50	2.42	4.23	16.63	1.42	15.21	3.60	18.81	2.09	9.0
18	80	13.74	1.96	1.77	3.88	21.35	.78	20.57	3.60	24.17	2.15	11.2
19	200	13.71	3.29	1.67	4.70	23.37	.70	22.67	3.00	25.67	2.62	9.8
20	250	8.00	1.52	.63	3.24	13.39	1.60	11.79	3.00	14.79	4.35	3.4
21	200	6.61	2.80	.82	2.70	12.93	.....	12.93	3.00	15.93	4.90	3.2
22	145	8.78	1.70	.38	3.96	14.82	.31	14.51	2.40	16.91	8.04	2.1
23	70	6.30	1.98	.76	7.92	16.96	.36	16.60	3.00	19.60	13.72	1.4
					PAWNEE COUNTY, KANS.							
1	75	$6.91	$2.88	$3.01	$4.40	$17.20	$2.72	$14.48	$6.00	$20.48	$1.05	19.5
2	470	6.46	2.51	3.33	4.26	16.56	1.36	15.20	4.80	20.00	1.08	18.5
3	120	6.07	1.91	3.47	4.41	15.86	.40	15.46	6.00	21.46	1.12	19.2
4	87	8.94	1.78	3.84	4.24	18.80	.06	18.74	4.50	23.24	1.16	20.0
5	135	6.99	3.86	1.33	4.57	16.75	10.70	6.05	4.50	10.55	1.20	8.8
6	140	4.26	2.91	3.46	5.24	15.87	.86	15.01	4.50	19.51	1.37	14.3
7	310	7.92	1.73	3.76	6.89	20.30	1.02	19.28	6.00	25.28	1.44	17.5
8	25	5.99	1.55	3.40	4.95	15.89	.68	15.21	4.50	19.71	1.52	13.0
9	160	8.86	2.03	3.32	3.17	17.38	1.97	15.41	6.00	21.41	1.56	13.8
10	110	6.16	2.49	2.74	4.68	16.07	.45	15.62	6.00	21.62	1.59	13.6
11	400	5.89	3.41	2.50	4.08	15.88	.10	15.78	4.80	20.58	1.66	12.4
12	240	6.96	2.00	2.69	7.27	18.92	1.30	17.62	4.80	22.42	1.67	13.5
13	80	10.84	2.67	3.55	7.29	24.35	1.40	22.95	6.00	28.95	1.70	17.0
14	140	7.28	3.00	2.36	6.13	18.77	1.42	17.35	5.40	22.75	1.75	13.0
15	80	6.92	2.20	2.25	6.16	17.53	1.33	16.20	4.50	20.70	1.88	11.0
16	305	5.75	2.21	1.91	5.59	15.46	.80	14.66	6.00	20.66	2.16	9.5
17	250	5.83	2.05	1.56	4.11	13.55	.09	13.46	4.80	18.26	2.28	8.0
					MCPHERSON COUNTY, KANS.							
1	45	$12.90	$4.02	$2.99	$4.09	$24.00	$1.71	$22.29	$7.20	$29.49	$1.68	17.8
2	33	11.49	2.58	3.71	5.78	23.56	.61	22.95	9.00	31.95	1.75	18.3
3	60	13.39	3.43	3.78	7.13	27.73	.....	27.73	9.00	36.73	1.88	18.9
4	20	7.94	2.70	3.31	9.72	23.67	3.10	20.57	9.00	29.57	1.90	15.0
5	120	11.02	4.06	2.96	4.98	23.02	.50	22.52	9.00	31.52	2.25	14.0
6	120	10.92	3.62	2.96	4.45	21.95	.74	21.21	6.00	27.21	2.27	12.0
7	60	9.94	2.97	2.07	4.24	19.22	1.50	17.72	7.50	25.22	2.47	10.2
8	80	10.88	3.60	2.22	5.24	21.94	.09	21.85	6.00	27.85	2.54	10.0
9	320	13.53	3.81	2.98	5.61	25.93	.67	25.26	9.00	34.26	2.64	13.0
10	80	11.22	2.75	1.83	5.09	20.89	.79	20.10	7.50	27.60	2.91	9.5
11	140	9.57	3.25	2.13	6.37	21.32	.36	20.96	9.00	29.96	3.09	9.7
12	50	13.35	2.56	2.08	4.36	22.35	.34	22.01	7.50	29.51	3.14	9.4
13	180	9.94	2.63	1.78	6.20	20.55	.50	20.05	7.50	27.55	3.94	7.0
					SALINE COUNTY, MO.							
1	90	$8.35	$3.01	$3.39	$5.95	$20.70	$14.89	$5.81	$18.00	$23.81	$1.21	19.7
2	40	9.58	3.67	3.14	6.71	23.10	2.79	20.31	13.50	33.81	1.50	22.5
3	100	15.87	3.86	3.67	7.54	30.94	1.00	29.94	10.80	40.74	1.70	24.0
4	40	7.80	3.12	5.04	3.90	19.86	1.07	18.79	15.00	33.79	1.88	18.0
5	100	13.43	3.48	2.73	4.29	23.93	1.45	22.48	12.00	34.48	1.92	18.0
6	85	16.50	3.49	3.49	5.22	28.70	.....	28.70	12.00	40.70	1.94	21.0
7	70	5.53	3.41	5.84	7.09	21.87	1.42	20.45	15.00	35.45	1.97	18.0
8	65	17.84	4.31	6.54	6.48	35.17	1.06	34.11	15.00	49.11	2.16	22.8
9	40	13.18	3.14	2.48	7.44	26.24	.....	26.24	9.00	35.24	2.31	15.3

TABLE XXXVII.—*Individual costs per acre on owned land, spring and winter wheat, 1919 (327 farms)*—Continued.

Record number.	Acres harvested.	Factors of cost, per acre.								Total net cost, with rent.		Yield per acre.
		Labor.	Material.	Thrashing.	Miscellaneous.	Total gross cost, without rent.	Credit.	Total net cost, without rent.	Rent (interest on investment).	Per acre.	Per bushel.	
						WINTER WHEAT—Continued.						
						SALINE COUNTY, MO.—Continued.						
10	$200	$8.58	$2.57	$1.92	$3.66	$16.73	$8.43	$8.30	$16.50	$24.80	$2.32	10.7
11	70	11.03	3.16	2.14	5.49	21.82	.....	21.82	15.00	35.82	2.34	15.7
12	65	5.98	3.32	3.28	5.15	17.73	.97	16.76	15.00	31.76	2.80	11.3
13	15	13.73	3.54	3.82	4.30	25.39	.32	25.07	9.00	34.07	2.84	12.0
14	75	14.02	3.29	1.96	4.72	23.99	.83	23.16	15.00	38.16	2.86	13.3
15	175	10.90	3.76	4.29	4.06	23.01	.14	22.87	18.00	40.87	2.92	14.0
16	37	8.29	3.46	1.97	6.59	20.31	4.05	16.26	15.00	31.26	3.04	10.3
17	30	13.96	3.19	2.18	9.64	28.97	4.20	24.77	12.00	36.77	3.11	11.8
18	65	20.32	3.75	1.90	5.22	31.19	.46	30.73	12.00	42.73	3.29	13.0
19	40	14.99	3.54	1.78	19.83	40.14	1.87	38.27	12.00	50.27	3.35	15.0
20	20	14.63	3.26	1.80	4.10	23.79	.30	23.49	13.50	36.99	4.25	8.7
21	40	15.13	3.44	1.50	9.81	29.88	4.06	25.82	12.00	37.82	5.20	7.3
						JASPER COUNTY, MO.						
1	52	$13.42	$5.33	$1.67	$4.49	$24.91	$0.78	$24.13	$8.10	$32.23	$1.29	25.0
2	145	10.50	6.18	1.34	6.69	24.71	4.03	20.68	7.80	28.48	1.41	20.2
3	34	14.26	5.00	1.52	4.41	25.19	.82	24.37	6.00	30.37	1.43	21.2
4	68	12.21	4.65	1.53	4.93	23.32	.81	22.51	6.00	28.51	1.52	18.8
5	130	12.93	3.96	1.64	6.42	24.95	.25	24.70	8.40	33.10	1.54	21.5
6	85	9.93	4.65	1.78	5.86	22.22	.52	21.70	9.00	30.70	1.54	20.0
7	17	18.29	7.65	2.03	7.11	35.08	5.29	29.79	9.00	38.79	1.55	25.0
8	55	15.15	4.94	1.54	4.71	26.34	3.00	23.34	9.00	32.34	1.62	20.0
9	140	13.74	5.41	1.55	4.89	25.59	.51	25.08	9.00	34.08	1.66	20.5
10	185	13.97	5.37	1.43	5.45	26.22	2.59	23.63	8.40	32.03	1.70	18.9
11	20	14.84	5.39	1.41	4.65	26.29	.65	25.64	6.00	31.64	1.71	18.5
12	75	15.54	6.67	1.72	5.90	29.83	.64	29.19	9.00	38.19	1.75	21.8
13	70	12.67	5.75	1.32	5.40	25.14	.43	24.71	7.50	32.21	1.79	18.0
14	85	13.55	5.28	1.29	4.32	24.44	1.00	23.44	7.50	30.94	1.85	16.7
15	30	15.84	8.17	1.20	4.51	29.72	5.33	24.39	6.00	30.39	2.07	14.7
16	39	23.90	4.62	1.76	6.73	37.01	.....	37.01	9.00	46.01	2.22	20.8
17	39	14.82	4.33	1.27	8.75	29.17	3.08	26.09	7.50	33.59	2.24	15.0
						ST. CHARLES COUNTY, MO.						
1	15	$9.48	$3.86	$2.86	$6.76	$22.96	$0.33	$22.63	$12.00	$34.63	$1.15	30.0
2	90	10.18	3.84	2.21	5.28	21.51	.56	20.95	7.50	28.45	1.19	24.0
3	144	12.34	4.21	2.21	4.01	22.77	.14	22.63	8.40	31.03	1.35	22.9
4	67	7.57	3.82	2.14	7.24	20.77	.37	20.40	12.00	32.40	1.39	23.3
5	35	12.73	2.94	2.01	4.16	21.84	.32	21.52	9.00	30.52	1.40	21.8
6	33	15.08	3.61	2.55	4.82	26.06	.42	25.64	13.50	39.14	1.44	27.3
7	52	11.80	3.70	1.81	4.17	21.48	.48	21.00	8.40	29.40	1.48	19.9
8	89	10.93	2.99	1.91	5.04	20.87	.44	20.43	12.00	32.43	1.49	21.7
9	60	13.84	3.25	2.03	5.33	24.45	.83	23.62	9.00	32.62	1.51	21.7
10	105	10.04	3.40	1.76	3.93	19.13	1.19	17.94	10.50	28.44	1.57	18.2
11	36	15.82	3.17	1.93	6.34	27.26	1.22	26.04	8.40	34.44	1.60	21.6
12	90	11.89	3.14	1.86	3.57	20.46	.....	20.46	12.00	32.46	1.62	20.0
13	20	12.48	3.55	1.83	4.41	22.27	.46	21.81	10.50	32.31	1.62	20.0
14	80	9.91	4.49	1.77	5.04	21.21	.....	21.21	9.00	30.21	1.63	18.5
15	54	13.35	3.53	1.73	5.87	24.48	.58	23.90	7.50	31.40	1.65	19.1
16	23	11.36	3.51	1.73	4.22	20.82	.51	20.31	10.50	30.81	1.69	18.3
17	70	11.73	3.48	2.10	7.52	24.83	.29	24.54	12.00	36.54	1.73	21.1
18	52	15.93	4.09	1.84	5.42	27.28	.....	27.28	9.00	36.28	1.80	20.2
19	70	9.45	3.59	1.69	5.21	19.94	.43	19.51	12.00	31.51	1.82	17.3
20	65	18.58	3.87	1.92	6.14	30.51	1.00	29.51	7.50	37.01	1.85	20.0
21	60	12.69	3.89	2.29	7.73	26.60	.50	26.10	18.00	44.10	1.86	23.8
22	110	13.43	3.92	1.89	4.96	24.20	.23	23.97	13.50	37.47	1.87	20.0
23	41	17.19	3.84	1.99	5.96	28.98	.41	28.57	9.00	37.57	1.88	20.0
24	40	18.63	6.69	2.00	6.97	34.29	.75	33.54	7.50	41.04	1.99	20.6
25	40	14.55	4.31	1.98	7.44	28.28	.30	27.98	12.00	39.98	2.00	20.0
26	38	13.12	5.22	1.88	5.41	25.63	.57	25.06	15.00	40.06	2.00	20.0
27	77	14.60	5.01	1.91	5.96	27.48	.52	26.96	15.00	41.96	2.02	20.8
28	55	17.67	4.71	1.77	6.01	30.16	.64	29.52	9.00	38.52	2.06	18.7
29	80	12.36	3.64	1.27	5.16	22.43	.38	22.05	7.50	29.55	2.15	13.8
30	42	14.87	3.32	1.42	5.19	24.80	.65	24.15	9.00	33.15	2.32	14.3
31	180	12.01	4.19	1.29	5.41	22.90	.27	22.63	9.00	31.63	2.48	12.8

TABLE XXXVII.—*Individual costs per acre on owned land, spring and winter wheat, 1919 (327 farms)*—Continued.

Record number.	Acres harvested.	Factors of cost, per acre.								Total net cost, with rent.		Yield per acre.
		Labor.	Material.	Thrashing.	Miscellaneous.	Total gross cost, without rent.	Credit.	Total net cost without rent.	Rent (interest on investment).	Per acre.	Per bushel.	
						WINTER WHEAT—Continued.						
						PHELPS COUNTY, NEBR.						
1	20	$6.48	$2.50	$0.82	$2.82	$12.62	$1.00	$11.62	$6.00	$17.62	$1.58	8.0
2	20	7.33	3.08	1.38	3.77	15.56	.....	15.56	6.00	21.56	1.66	13.0
3	100	8.20	3.86	1.63	4.17	17.86	.14	17.72	7.50	25.22	1.68	15.0
4	235	9.49	2.87	1.53	4.97	18.86	.....	18.86	6.90	25.76	1.86	13.8
5	110	9.56	2.82	1.53	4.61	18.52	.....	18.52	7.50	26.02	1.86	14.0
6	43	12.30	2.84	1.66	4.34	21.14	.....	21.14	7.50	28.64	1.91	15.0
7	80	9.19	3.37	1.20	3.23	16.99	2.50	14.49	6.60	21.09	1.92	11.0
8	430	9.70	2.67	1.28	3.44	17.09	.....	17.09	7.50	24.59	2.05	12.0
9	100	8.73	2.65	1.05	4.88	17.31	1.10	16.21	7.50	23.71	2.43	9.8
10	140	9.40	2.60	1.02	3.91	16.93	.48	16.45	7.50	23.95	2.48	9.6
11	120	9.74	3.08	1.06	3.90	17.78	.42	17.36	8.40	25.76	2.69	9.6
12	90	11.22	2.42	.94	3.56	18.14	.....	18.14	6.00	24.14	2.76	8.8
13	105	9.09	2.38	.75	3.67	15.89	.....	15.89	7.50	23.39	3.11	7.5
14	55	6.38	2.53	.43	5.34	14.68	.42	14.26	9.00	23.26	6.33	3.7
						SALINE COUNTY, NEBR.						
1	50	$10.59	$4.36	$1.83	$5.95	$22.73	$0.20	$22.53	$9.00	$31.53	$1.43	22.0
2	55	15.15	4.72	2.86	4.74	27.47	.45	27.02	9.00	36.02	1.61	22.4
3	30	16.44	5.19	2.28	6.47	30.38	2.50	27.88	12.00	39.88	1.69	23.6
4	48	13.30	3.96	2.19	5.43	24.88	.31	24.57	12.00	36.57	1.76	20.8
5	65	10.15	4.55	1.72	6.39	22.81	.....	22.81	12.00	34.81	1.93	18.0
6	50	13.33	3.64	1.99	6.97	25.93	.50	25.43	15.00	40.43	1.93	21.0
7	85	12.97	3.38	2.39	5.05	23.79	.....	23.79	15.00	38.79	1.94	20.0
8	45	13.42	3.58	1.61	5.49	24.10	.22	23.88	9.00	32.88	2.05	16.0
9	40	11.62	3.58	1.76	3.97	20.93	.....	20.93	16.50	37.43	2.08	18.0
10	35	19.16	4.20	1.94	6.03	31.33	.....	31.33	10.50	41.83	2.09	20.0
11	50	14.39	3.90	1.80	7.31	27.40	.....	27.40	12.00	39.40	2.10	18.8
12	55	16.62	7.03	2.02	8.44	34.11	.82	33.29	15.00	48.29	2.10	23.0
13	40	13.87	3.38	1.85	5.62	24.72	.38	24.34	12.00	36.34	2.14	17.0
14	90	18.51	5.52	2.02	5.04	31.09	.33	30.76	12.00	42.76	2.16	19.8
15	16	17.24	4.07	1.80	4.66	27.77	.....	27.77	16.50	44.27	2.21	20.0
16	30	19.11	5.25	1.80	6.33	32.49	.33	32.16	12.00	44.16	2.21	20.0
17	60	13.30	4.22	1.68	5.86	25.06	.40	24.66	12.00	36.66	2.29	16.0
18	15	14.69	3.97	1.75	7.29	27.70	.50	27.20	12.00	39.20	2.31	17.0
19	22	13.43	4.31	1.28	5.46	24.48	.91	23.57	12.00	35.57	2.37	15.0
20	122	11.15	3.90	2.05	6.42	23.52	.....	23.52	15.00	38.52	2.49	15.4
21	65	17.58	3.85	1.48	5.87	28.78	1.15	27.63	15.00	42.63	2.51	17.0
22	90	15.73	4.63	1.56	6.02	27.94	.33	27.61	15.00	42.61	2.61	16.3
23	74	21.50	4.31	1.94	9.87	37.62	.....	37.62	12.00	49.62	2.64	18.8
24	20	17.27	3.68	1.85	5.85	28.65	.50	28.15	12.00	40.15	2.77	14.5
25	12	17.09	3.38	1.28	6.32	28.07	.42	27.65	12.00	39.65	2.83	14.0
26	50	15.55	5.50	1.08	5.01	27.14	.....	27.14	9.00	36.14	3.61	10.0
27	30	14.65	4.34	1.24	5.19	25.42	.20	25.22	14.40	39.62	3.96	10.0
						KEITH COUNTY, NEBR.						
1	450	$8.09	$1.56	$2.07	$4.04	$15.76	$0.44	$15.32	$3.90	$19.22	$0.96	20.0
2	130	13.02	2.14	2.94	5.18	23.28	.35	22.93	5.40	28.33	1.01	28.0
3	65	11.94	2.23	2.61	8.33	25.11	.23	24.88	4.80	29.68	1.19	25.0
4	150	8.24	2.77	2.49	9.65	23.15	.06	23.09	8.40	31.49	1.35	23.3
5	60	12.64	2.20	1.96	4.86	21.66	.34	21.32	4.50	25.82	1.37	18.8
6	60	7.53	2.20	1.44	5.41	16.58	.10	16.48	6.00	22.48	1.50	15.0
7	100	7.32	2.00	1.22	2.74	13.28	.....	13.28	6.00	19.28	1.57	12.2
8	65	9.29	2.98	2.05	6.45	20.77	.....	20.77	7.50	28.27	1.60	17.6
9	100	11.69	2.83	1.69	4.88	21.09	.25	20.84	6.00	26.84	1.68	16.0
10	40	13.86	2.50	1.60	3.40	21.36	.....	21.36	6.00	27.36	1.82	15.0
11	65	12.06	2.49	1.41	5.31	21.27	.31	20.96	7.50	28.46	1.99	14.3
12	200	5.44	2.25	1.11	4.84	13.64	.....	13.64	6.00	19.64	2.00	9.8
13	20	15.07	2.50	1.09	4.02	22.68	.25	22.43	2.40	24.83	3.08	8.0

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 944

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JOHN R. MOHLER, Chief

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THE ALCOHOL TEST AS A MEANS OF DETERMINING QUALITY OF MILK FOR CONDENSERIES.

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REVIEW OF PREVIOUS WORK.

The urgent necessity for some means of determining the quality of milk received at condenseries and other dairy manufacturing plants has resulted in the continued use of the acid test even after its defects have become generally recognized. This test is based on the assumption that a titratable acidity above the normal for fresh milk indicates an increase in acidity due to bacterial action.

It is well known, however, that a certain part of the alkali added to milk to obtain an end point with any given indicator is combined with constituents of the milk other than the acids. While this has been recognized it has not been generally realized how great a variation in the apparent acidity may be due to this cause. It has been recently pointed out by Rice (1)[1] that the casein and the phosphates both combine with alkali and are subject to a sufficient variation to cause in some instances an apparent high acidity in fresh milk.

Our own experience, which is not unusual, has shown that not infrequently milk rejected because of high acidity was fresh milk in which bacterial action was highly improbable. In making evaporated milk the most essential characteristic is the ability of the milk

[1] See list of references at end of bulletin.

to withstand a temperature sufficiently high to insure the subsequent sterilization without causing an objectionable curd. While it is assumed, and no doubt correctly, that acidity is an important factor in determining the coagulating point of concentrated milk, it is by no means certain that other factors may not be of equal or even greater importance. Sommer and Hart (2) have shown that there is no consistent relation between the titratable acidity and the heat coagulating point of milk. This they found also to be true of the hydrogen-ion concentration or true acidity of the fresh milk, but they express the opinion that it may become a factor under commercial conditions. They found, on the other hand, that the variations which occur normally in certain of the ash constituents have an important part in determining the temperature at which it coagulates.

The titration of milk in the usual way will give no indication of the condition of the ash and may be very misleading as to the hydrogen-ion concentration.

The alcohol test has been used to a limited extent for determining the quality of milk with special reference to its sanitary condition.

This test is usually made by mixing equal volumes of milk with 68 to 75 per cent alcohol and observing whether a coagulation results. It is generally considered that a coagulation indicates bacterial change in the milk, but Auzinger (3) shows that fresh milk not infrequently coagulates under these conditions and offers some evidence to show that it is due to changes in the milk salts, particularly in the calcium. Ayers and Johnson (4) show that while the alcohol test becomes positive when an appreciable amount of acid or rennet is produced in the milk there is no consistent relation between the alcohol test and the total number of bacteria present.

They found that while the addition of acid phosphates to milk increased the tendency to coagulate with alcohol, the neutral or dibasic phosphate had the opposite effect. When dibasic phosphate is added to milk considerably more acid is required to produce a positive alcohol test than with the normal milk.

While the work of Ayers and Johnson shows that the alcohol test is not a reliable index of the sanitary quality of the milk, there is a possibility that its action on milk may be correlated with the heat coagulation point of the evaporated milk in such a way as to render it of some value in grading milk in condenseries.

TEST METHODS USED.

The alcohol test as used in this investigation was made by mixing equal parts of 75 per cent alcohol and milk and observing whether coagulation takes place. In case the milk shows a visible coagulation

it is considered unsafe from the standpoint that the milk after evaporation will not stand the heat necessary for sterilization without becoming curdy. The test is practical and easy to make at the weigh room. The test as used in this work was made by adding 1 c. c. of milk to a small test tube containing 1 c. c. of alcohol and mixing at once by inverting once or twice while holding a finger over the top. Any reaction that takes place will be very quickly evident, the large majority of tests showing coagulation immediately or giving no reaction at all. The gradation of coagulation is shown by the size of the curd particles formed. Unless the curd particles formed are small the reaction is not at all difficult to distinguish, even by one not familiar with the test. A mixture of milk and alcohol giving a negative reaction immediately breaks clear from the walls of the test tube, while a mixture giving a coagulation of fine particles will leave the walls of the test tube cloudy. Mixtures showing a medium or large particle curd formation are readily discernible because of the adherence of the curd particles to the walls of the test tube.

In the work of grading the milk at a condensery on a commercial basis two small brass dippers of 2 c. c. capacity each were used. Thirty test tubes arranged in a block of wood 3 inches wide, 2 inches deep, and 18 inches long, having three rows of holes of the proper diameter and depth, were first filled with 2 c. c. of the 75 per cent alcohol by means of one of the brass dippers. Two men working together then went through the individual cans, taking 2 c. c. of milk from each and mixing it with the 2 c. c. of alcohol. No more time was required than is necessary in making the acidity test.

The first work attempted with the alcohol test was to determine whether any correlation existed between the coagulation and the acid content of milk as measured by the usual titration method. Samples of milk were taken from individual patrons at the weigh room of the Grove City, Pa., creamery for the observations made. Reactions with 75 per cent ethyl alcohol and titratable acidity were determined shortly after taking samples and at stated intervals on those not showing positive coagulation with alcohol, until such action occurred. All samples which did not show coagulation with alcohol at the outset were held in a water bath at 35° to 37° C. (95° to 98.6° F.) during subsequent observations. A tabulation of 211 samples of milk handled according to the method outlined shows conclusively that there is no direct relation between the coagulation of the milk with 75 per cent alcohol and the acid content of milk as measured by the titration method.

EXPERIMENTS AT GROVE CITY CREAMERY.

COMPARISON OF ACIDITY AND ALCOHOL TESTS OF MILK FOR CONDENSING.

Finding no consistent relation between the coagulation of milk by alcohol and its acidity content as shown by the titration method, work was started to ascertain the relative value of the two tests. Samples of milk, representing all conditions met with at the condensery, were taken at the weigh room of the Grove City creamery. Five pounds of each sample selected—which in the large majority of cases represented a mixed milk of some particular patron's herd—was evaporated in a 10-liter flask under a vacuum of 25 to 27 inches to a concentration of 2¼ to 1, the time required being from 50 to 70 minutes, with a temperature of 40° to 50° C. (104° to 122° F.). The evaporated milk was placed in baby-size tins and sterilized in an autoclave for 30-minute intervals at 121.1°, 112.8°, and 107.2° C. (250°, 235°, and 225° F.). Portions of evaporated milk in 100 c. c. Erlenmeyer flasks were run in the autoclave at the temperatures used and also at 100° C. (212° F.) for 30 minutes to note the extent of coagulation. When sterilization at 112.8° C. (235° F.) for 30 minutes indicated that the product would not stand a higher processing, the next lower temperature was used, only two temperatures higher than 100° C. (212° F.) being used. The cooled cans of sterilized milk were shaken for one minute before examination for general physical appearance and curdiness.

The main observation of the sterilized samples of evaporated milk concerned the extent of coagulation and whether or not they showed curdiness after shaking. Curdiness of shaken samples was determined by the physical appearance of the product and by mixing a portion of it with hot water. In reporting on whether or not the sterilized samples were curdy after shaking, the temperature of 112.8° C. (235° F.) for 30 minutes was used as a standard of comparison. In the large majority of instances the curdiness was pronounced enough to leave no doubt as to the accuracy of decision, and the sample sterilized at the lower temperature quite generally substantiated the classification given on the basis of the standard temperature used. On the other hand, the samples showing no curdiness after sterilization were in most cases not at all difficult to classify, as they showed, in general, less coagulation even with the higher temperature.

Table 1 shows the results of sterilization of 90 samples of milk of varying acidity, 45 of which coagulated with 75 per cent alcohol. Forty-three of the 45 when evaporated and sterilized at 112.8° C. (235° F.) for 30 minutes showed curdiness after shaking. Coagulation of practically all these samples when evaporated was very pronounced, in some instances being so hard that it was impossible in

any manner to reduce the extreme lumpiness. Some of the samples of low acidity showed as objectionable a curdiness as those of the higher acidity, indicating the reliability of the alcohol test and unreliability of the acid test in picking out those which will not stand the sterilization necessary in manufacturing evaporated milk.

The table shows also the result of sterilization upon 45 samples of milk of varying acidity, all of which showed a negative reaction with 75 per cent alcohol. Forty-two of the 45 when evaporated and sterilized showed no curdiness after shaking.

TABLE 1.—*Comparison of alcohol and acid tests at Grove City creamery. Milk concentrated 2¼ to 1 and sterilized at 235° F. for 30 minutes. Effect of sterilization noted after shaking for 1 minute.*

Acidity.	Coagulation with 75 per cent alcohol.			No coagulation with 75 per cent alcohol.		
	Total samples.	Effect of sterilization.		Total samples.	Effect of sterilization.	
		Curdy.	Not curdy.		Curdy.	Not curdy.
Per cent.						
0.14 to 0.15	3	3	0	.....	.....	.....
.15 to .16	5	5	0	1	0	1
.16 to .17	10	8	2	9	0	9
.17 to .18	11	11	0	12	1	11
.18 to .19	10	10	0	11	1	10
.19 to .20	5	5	0	10	0	10
.20 to .21	1	1	0	2	1	1
Total....	45	43	2	45	3	42

It seems quite certain that there is some condition of raw milk coagulating with 75 per cent alcohol, making it impossible to sterilize without getting a curdy finished product, for such milks when evaporated and sterilized give a much firmer coagulation than those showing a negative reaction with 75 per cent alcohol. In some instances the coagulation, even at the lower temperatures used, is such that the product turns to a hard, cheesy mass incapable of improvement with long-extended shaking. Figure 1, showing the type of curd obtained in sterilization, indicates clearly the difference which must exist in the condition of milk coagulated with 75 per cent alcohol. Only 6.7 per cent of the samples made from milk coagulating with alcohol gave a soft curd, the remainder giving either a firm or a hard curd, both of which are as a rule difficult to shake out to give a product showing no curdiness. With the evaporated samples from raw milk not coagulating with 75 per cent alcohol 88.9 per cent gave either a soft curd or no coagulation at all, the remaining 11.1 per cent giving a firm curd. The soft curds shake out very easily, giving a smooth-bodied product of good consistency showing no curdiness.

The difference in the effect of sterilization upon evaporated milk made from raw milk, showing negative or positive reaction with 75 per cent alcohol is further emphasized in figure 2, which shows the curdiness found at all temperatures used.

To get complete figures on all the four temperatures it was assumed in compiling these data that a sample showing curdiness at a temperature actually used would show curdiness at any higher temperature. With raw milks showing negative reaction with 75 per

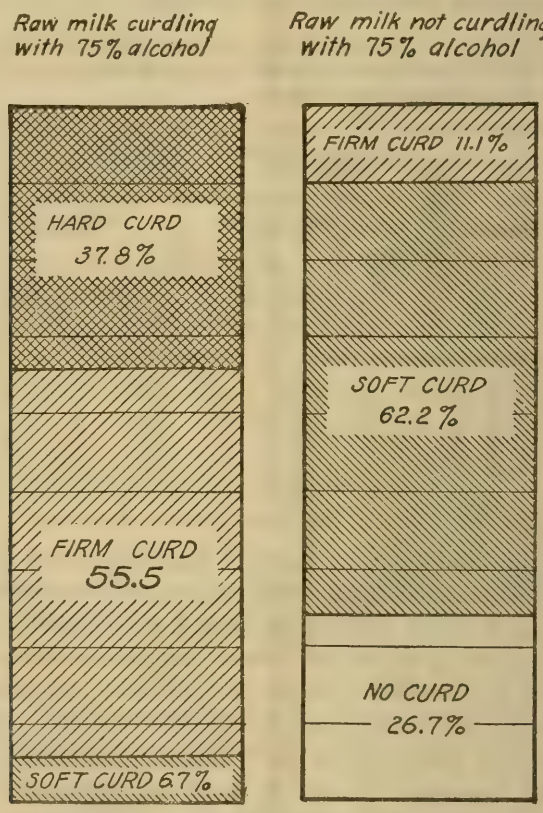

FIG. 1.—Types of curd obtained in sterilization of evaporated milk.

cent alcohol only 4.4 per cent of the evaporated samples showed curdiness at 100° C. (212° F.) and 107.2° C. (225° F.) for 30 minutes; 6.6 per cent at 112.8° C. (235° F.) for 30 minutes; and 31.1 per cent at 121.1° C. (250° F.) for 30 minutes. With raw milks coagulating with 75 per cent alcohol, 57.7 per cent showed curdiness at a temperature of 100° C. (212° F.) for 30 minutes, 80 per cent at 107.2° C. (225° F.) for 30 minutes, 95.5 per cent at 112.8° C. (235° F.) for 30 minutes, and 100 per cent at 121.1° C. (250° F.) for 30 minutes. These figures show quite strikingly a difference in

condition of milk coagulating with 75 per cent alcohol, which renders it impossible to manufacture from it evaporated milk that will not give curdiness when using a sterilizing temperature necessary to insure a complete destruction of the bacteria. Samples of raw milk giving a coagulation with alcohol and showing curdiness when evaporated and sterilized can be sterilized without showing curdiness

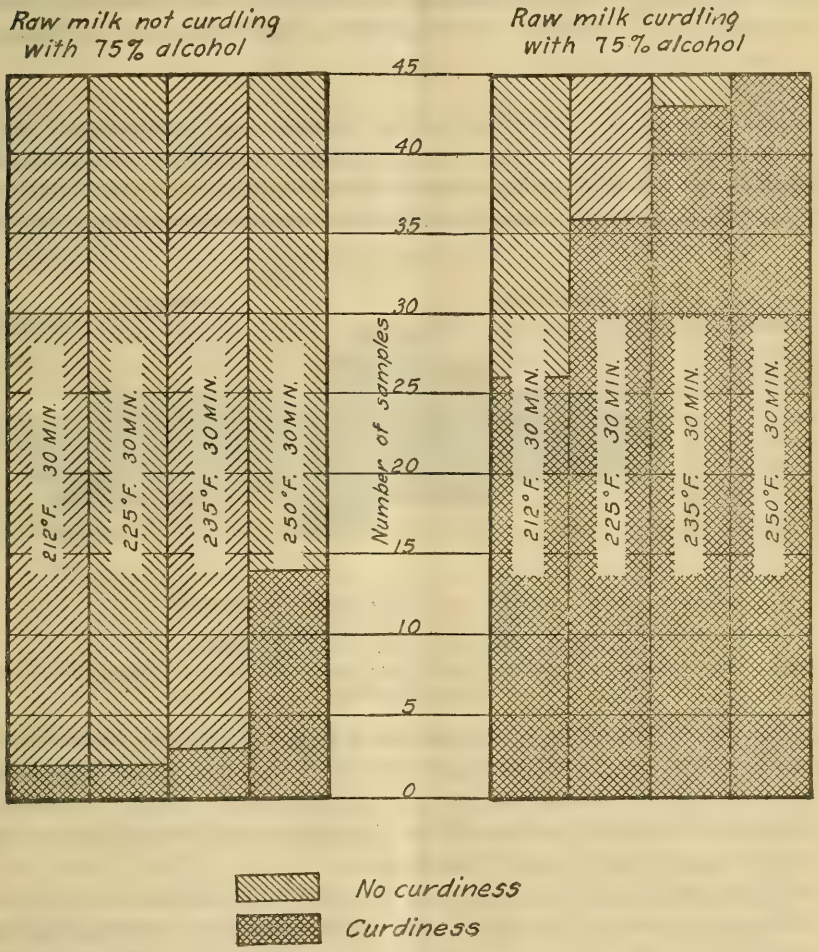

FIG. 2.—Extent of curdiness in evaporated milk sterilized at different temperatures.

of the finished product in a mixture containing from 60 to 70 per cent of raw milks giving a negative alcohol test. This fact would account for the variation in heat taken by different batches from day to day.

Undoubtedly there is received at every condensery some milk which will not stand the required heat when evaporated by itself, but which will go through all right when mixed with other milk. If the

proportion of this milk is not too high no trouble will be experienced, but the proportion in some batches may be such as to cause considerable trouble.

It is interesting to know that raw milk with a low titratable acidity and which coagulates with alcohol and shows curdiness after evaporating and sterilizing can be made to stand sterilization with no resulting curdiness by mixing with it the proper amount of milk showing a high titratable acidity but no coagulation with alcohol.

RELATIVE VALUE OF ACID AND ALCOHOL TESTS.

The value of any practical test for determining the quality of milk for condensing must depend largely upon its ability to determine whether or not that milk, when evaporated to the required density, will withstand the necessary sterilizing temperature without becom-

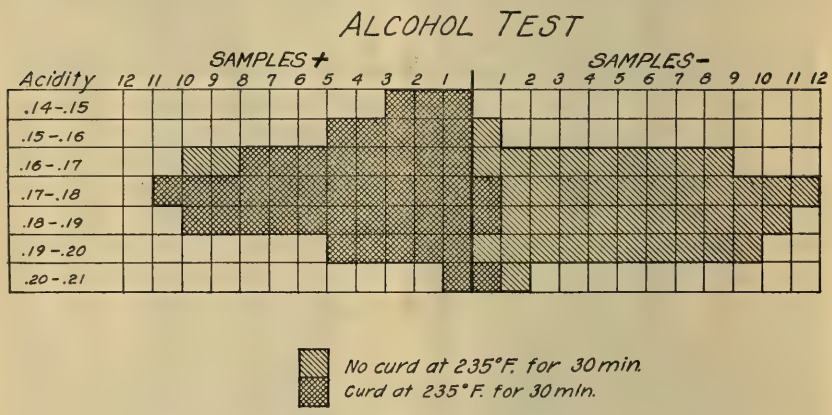

FIG. 3.—The relation of titratable acidity and the alcohol test to coagulation of the evaporated milk.

ing curdy. The flavor and odor are things which have to be determined by the senses of taste and smell. The tendency of milk with objectionable flavor and odor to coagulate with alcohol indicates additional value of the test from this standpoint, especially where little attention is given to these factors.

The preliminary work indicated clearly the unreliability of the acid test, as ordinarily used in the condensery, for determining the quality of milk for condensing. A comparison of the acid and alcohol tests in determining what milk when evaporated would stand sterilization without showing curdiness reveals the following:

Of 90 samples of raw milk taken at the weigh room and representing a wide range of condition, 46 samples of the finished evaporated milk showed curdiness after sterilization and shaking. Forty-four of the evaporated-milk samples withstood sterilization, showing no curdiness after shaking. Analysis of Table 2 and figure 3 shows that the alcohol test would have rejected 43 of the 46 samples

that showed curdiness after sterilization and shaking, while it would have rejected 2 out of 44 that were all right; that is, showed no curdiness. The acid test would have rejected 18 of the 46 samples showing curdiness after sterilization and shaking, while it would have rejected 21 of the 44 that showed no curdiness.

The following tabulation shows the percentage of satisfactory and unsatisfactory milk samples that would have been retained or rejected by the alcohol and acidity tests:

	Alcohol test. (Per cent.)	Acidity test. (Per cent.)
Satisfactory milk samples retained	95.5	52.3
Satisfactory milk samples rejected	4.5	47.7
Unsatisfactory milk samples retained	6.5	60.9
Unsatisfactory milk samples rejected	93.5	39.1

Table 2 gives a more concrete comparison of the relative value of the alcohol and acid tests in the work done at Grove City, Pa.

TABLE 2.—*Relative value of alcohol and acidity tests on samples run at Grove City, Pa.*

Kind of samples.	Number of samples.	Alcohol test.		Acidity test.	
		Times correct.	Times incorrect.	Times correct.	Times incorrect.
Satisfactory	44	42	2	21	23
Unsatisfactory	46	43	3	18	28
Total	90	85	5	39	51
Per cent	100	94.4	5.6	43.3	56.7

EXPERIMENTS AT CONDENSERIES.

WORK AT FACTORY A.

Realizing the importance of trying out the alcohol test under other, including commercial, conditions, the work was extended to a condensery, which is designated as Factory A,[2] where considerable difficulty had been experienced in making an evaporated milk meeting the requirements of 26.15 per cent total solids and 8 per cent fat. The small laboratory apparatus used in the Grove City work was set up in the laboratory of this plant and work of the same nature as that done at Grove City carried on. Samples of individual patrons' milk showing positive or negative reaction with alcohol were condensed to bring the product as nearly as possible to 18.15 per cent solids not fat, that being the portion of the evaporated milk causing the difficulty in sterilization. It was the aim to have the samples that were evaporated from raw milk showing no coagulation with alcohol slightly above the point of 18.15 per cent solids not fat, and

[2] The assistance of F. B. Evans in the work at this factory is acknowledged.

those from raw milk showing coagulation with alcohol slightly below this point. Samples not showing close to this schedule are not included in the discussion of results.

The samples of evaporated milk put up in baby-size cans were run in a Berlin pilot sterilizer used by the plant in determining the amount of heat the different runs would stand.

The results of this work did not agree closely with those obtained at Grove City. All the samples of raw milk showing coagulation with alcohol gave an evaporated milk that showed curdiness after sterilization at a temperature of 112.8° C. (235° F.) for 30 minutes. As the samples of raw milk, showing no coagulation with alcohol, gave evaporated milks that in the majority of cases also showed curdiness, no real comparison could be made as to the relative merit of the alcohol and acid tests.

Table 3 shows the result of the work done at Factory A on individual patrons' milk samples. Of the 22 samples of raw milk showing no reaction with alcohol, 14, after evaporating, showed curdiness at the standard sterilizing temperature used, which happened to be about what was found necessary to insure a safe-keeping milk, while 8 showed no curdiness. Of the 12 samples of raw milk showing coagulation with alcohol, all showed curdiness after they were evaporated and subjected to the standard sterilizing temperatures.

TABLE 3.—*Relation of alcohol test and titratable acidity in Factory A. Evaporated milk having close to 18.15 per cent solids not fat. Effect of sterilization noted after shaking for 1 minute.*

Acidity.	Raw milk not coagulating with 75 per cent alcohol.			Raw milk coagulating with 75 per cent alcohol.		
	Total samples.	Effect of sterilization.		Total samples.	Effect of sterilization.	
		Curdy.	Not curdy.		Curdy.	Not curdy.
Per cent.						
0.11 to 0.12	.....	.....	.....	1	1	0
.12 to .13	4	2	2	0	0	0
.13 to .14	3	2	1	3	3	0
.14 to .15	4	2	2	3	3	0
.15 to .16	3	3	0	4	4	0
.16 to .17	5	4	1	0	0	0
.17 to .18	3	1	2	1	1	0
.18 to .19	.....	.....	.....	0	0	0
Total	22	14	8	12	12	0

The alcohol test was further tried out on a commercial basis in this plant. The individual cans of milk received at the intake were tested with alcohol according to the method already described. All the milk showing no coagulation with alcohol was run in a separate vat and condensed in the large factory pan as a separate batch.

A composite sample of the milks showing coagulation with alcohol, along with a sample of that showing no coagulation, was run in the laboratory apparatus as a means of comparison. Out of 4 trials the raw milk showing coagulation with alcohol gave an evaporated milk that in all 4 cases showed curdiness after sterilization at the standard temperature, while the evaporated milk from the raw milks showing no coagulation with alcohol showed curdiness in 3 out of 4 cases. The 4 batches of milk, the individual cans of which showed no coagulation with alcohol and which were run in the large factory pan, all showed curdiness after sterilization. Several laboratory runs made on milk taken from the large receiving vat at different times, to get representative samples of the milk received, failed in all instances to give an evaporated milk that would meet the required standard and not show curdiness after sterilizing and shaking.

The general failure of milk, accepted on the acid test at this condensery, to withstand the necessary heat after being evaporated, suggested that it might be due to a deficiency in the composition and balance of milk salts, as reported by Sommer and Hart (2). The fact that the addition of a small amount of dibasic potassium phosphate, which is a normal constituent of milk, corrected the excessive tendency of the milk to curdle in sterilization indicates that this assumption was correct.

Consideration of the manner in which milk at this plant was handled, in connection with the results obtained, indicates that the conditions were quite different from those that the average condensery has to contend with, and for this reason it appeared highly desirable to try out the alcohol test at another place.

WORK AT FACTORY B.

The work was then continued in a condensery, designated Factory B, located in a region where dairying forms a minor part of the farm operations. As a result of this condition the milk received was not of good quality. All the work done at this plant was on a commercial basis, the milk being graded at the intake and run into separate tanks according to its reaction with alcohol. Separate runs of the milk showing, respectively, coagulation and no coagulation with alcohol, were made in the factory pans, and after retaining the required amount of each batch of evaporated product for the experimental work, they were mixed in one tank and handled in the usual manner by the factory. Because of the small proportion of milk received that showed coagulation with alcohol, the batches from this kind of milk were smaller and in some cases it was necessary to hold them over until the next day in order to get enough for a run in the

factory pan. When this was found necessary the milk was cooled to a very low temperature and held in that condition overnight; only a very slight increase in acidity was shown.

The evaporated milk from each run was standardized to show close to 18.15 per cent solids not fat. The samples from the raw milk showing no coagulation with alcohol were standardized to show slightly above this figure. All samples were sterilized in one of the large Fort Wayne sterilizers used regularly by the condensery.

Four trials of grading and condensing milk on a commercial basis were made in this factory. The evaporated milk from the raw milks showing no coagulation with alcohol in all cases came through the sterilization process in fine shape, producing no curdiness and indicating that they would have stood more heat; in all four cases, also, the evaporated milk from raw milks showing coagulation with alcohol gave a pronounced curdiness that could not be removed by prolonged shaking.

TABLE 4.—*Results obtained by grading with the alcohol test at Factory B.*

Raw milk.		Acidity.	Reaction to alcohol.	Solids not fat in evaporated milk.	Sterilization of evaporated milk.
Batch No.	Weight.				
	Pounds.	*Per cent.*		*Per cent.*	
1.....	12,400	0.140	−	17.96	No curd.
2.....	4,250	.170	+	17.06	Curdy.
3.....	10,100	.150	−	18.53	No curd.
4.....	9,100	.175	+	18.16	Curdy.
5.....	11,500	.165	−	18.24	No curd.
6.....	9,100	.175	+	18.16	Curdy.
7.....	12,400	.145	−	18.25	No curd.
8.....	6,300	.160	+	17.91	Curdy.

Table 4 gives the data on the four trials of grading and condensing at this establishment. The titratable acidity of the lots of milk showing coagulation with alcohol is somewhat higher than that of the milk showing no coagulation with alcohol. We have no definite data that will enable us to say this difference in acidity would account for the difference in coagulation. In order to throw some light on this question, four cans of the sterilized milk were sent to the laboratory where the hydrogen-ion concentration or true acidity was determined with the following results:[3]

Lot.	pH.
5	5.96
6	5.80
7	5.90
8	5.84

[3] The determinations were made by H. F. Zoller, of the Dairy Division.

While in each case the real acidity of the lot coagulating with alcohol and curdling in sterilization is higher, the difference is so small that it is very doubtful if it would more than counteract the effect of the higher solids of the corresponding lot.

CONCLUSIONS.

1. The acid test as ordinarily used will reject a portion of the unsatisfactory milks, but as a whole it is unreliable and inadequate as a means of determining the quality of milk for condenseries where evaporated milk is manufactured.

2. There is no direct relation between the coagulation of milk with alcohol and its titratable acidity, but milks high in titratable acidity as a result of fermentation will in the large majority of cases show coagulation with alcohol.

3. The alcohol test shows good possibilities as a practical and reliable test for determining the quality of milk for condenseries making evaporated milk. How generally the test can be applied will require further investigation at other condenseries. It is believed that it can be used to advantage in a large majority of average factories.

LIST OF REFERENCES.

(1) Rice, Frank E.
1919. Milk with high apparent acidity. *In* Science, N. S., v. 50, no. 1296, p. 424.

(2) Sommer, H. H., and Hart, E. B.
1919. The heat coagulation of milk. *In* Jour. Biol. Chem., v. 40, no. 1, p. 137–151.

(3) Auzinger, August.
1909. Studien über die Alkoholprobe der Milch, ihre Verwendbarkeit zum Nachweis abnormer Milchen und ihre Beziehungen zu anderen Prüfungsmethoden pathologischer Milch. *In* Milchw. Zentbl., v. 5, no. 7, p. 293–315; no. 8, p. 352–370; no. 9, p. 393–413; no. 10, p. 430–446.

(4) Ayers, S. Henry, and Johnson, William T., Jr.
1915. The alcohol test in relation to milk. U. S. Dept. Agr., Bul. no. 202.

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BULLETIN No. 945

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER May 27, 1921

THE INFLUENCE OF CALCIUM AND PHOSPHORUS IN THE FEED ON THE MILK YIELD OF DAIRY COWS.

By Edward B. Meigs, *Physiologist*, and T. E. Woodward, *Dairy Husbandman, Dairy Division.*

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DAIRY PRACTICES AT THE GOVERNMENT FARM AT BELTSVILLE.[1]

Opportunities for observing the effects of the feed on milk secretion have been rather favorable on the dairy experimental farm at Beltsville, Md., where the authors are stationed. Since 1912 a herd of from 50 to 100 cows, some of which are purebred Guernseys, Jerseys, or Holsteins, and some grades, has been maintained here. Daily records have been kept of the milk yields throughout, and yearly records of the feed consumed up to 1918. Since 1918 monthly or daily records of the rations have been kept. The fat in the milk of each cow has been determined once a month, and from the results so obtained the monthly and yearly yields of fat have been calculated. The feeds chiefly used have been corn meal, wheat bran, cottonseed

[1] The authors wish to acknowledge the valuable services of H. J. Nedrow, H. T. Converse, and W. E. Benscoter. Messrs. Nedrow and Converse were the herdsmen at the Beltsville farm during the period when the experiments were carried out, and they supervised the feeding and care of the experimental animals. Mr. Benscoter was responsible for the feeding in a number of cases, and carried out this part of the work with unusual care and accuracy.

meal, linseed meal, alfalfa and other legume hays, and corn silage and stover. Most of the cows have had a little pasture in the summer, but not enough to make up any considerable proportion of the total amount of feed eaten in the year.

The aim has been to feed the cows as much protein as is required by the most liberal of the American feeding standards, to keep them in good condition, to have them calve once a year, and to have them dry each year for 6 to 8 weeks before calving. It has generally happened in practice that the cows were fed a little less liberally than is demanded by the Savage and Eckles standards (9)[2] for the first two or three months after calving, and a little more liberally later. When they were dry they were usually fed 4 pounds of grain mixture B,[3] 4 pounds of legume hay, and as much silage as they would clean up. When the hay was alfalfa and the amount of silage eaten daily 30 pounds, which was the most usual state of things, this ration provided 1.29 pounds of digestible crude protein and 10.29 pounds of total digestible nutriment daily. After subtracting the maintenance requirement for a 1,000-pound cow, this would allow 0.59 pound protein and 2.37 pounds total nutriment daily for the growth of the unborn calf, which, according to the results obtained by Eckles (3), ought to be sufficient.

We have recently calculated the protein and total nutriment in the yearly rations of a number of cows from the general herd and have compared these quantities with those required for their maintenance and for their milk and fat yield according to the Savage standard. The results have shown that the cows usually received rations a little more liberal than those demanded by that standard.

During the last two years a number of the purebred Holsteins have been run on official test. In order to increase their milk yield their rations were made decidedly more liberal than those called for by any of the feeding standards. During the milking period they received daily about 12 pounds of alfalfa hay, 20 pounds of corn silage, and as much grain as they could clean up without getting sick; they usually ate 18 to 20 pounds a day of grain mixture F. They were fed heavily also before their calves were born; for 60 days or more before calving they usually received about 15 pounds of grain mixture F, 12 pounds of alfalfa hay, and 25 pounds of corn silage, a ration containing approximately four times as much protein and two and one-half times as much total nutriment as the routine ration fed to the dry cows of the general herd.

The cows on test gave from 15,000 to 20,000 pounds of milk in the year; that is, three to four times as much as most of the cows in the general herd. A part of this larger yield is due to the fact that

[2] The figures in parentheses refer to "Literature cited" at end of paper.
[3] See list of grain mixtures used in experiments, on p. 25.

the test cows were better bred, but a part also is due to the larger quantity of feed they consumed. How much of the increased milk yield to attribute to each of these factors is a question of great practical interest.

STANDARD RATIONS INSUFFICIENT FOR OPTIMUM MILK YIELD.

The cycle of lactation consists of two phases which may be called the preparatory and the active phases. Considerable changes go on in the udder of a cow for some time before her calf is born, and usually make themselves manifest by an increase in size and congestion of that organ. There is no doubt that the amount of the subsequent milk yield largely depends on these changes, and it is highly probable that the changes themselves depend on the state of nutrition in which the animal happens to be for the few weeks before her calf is born.

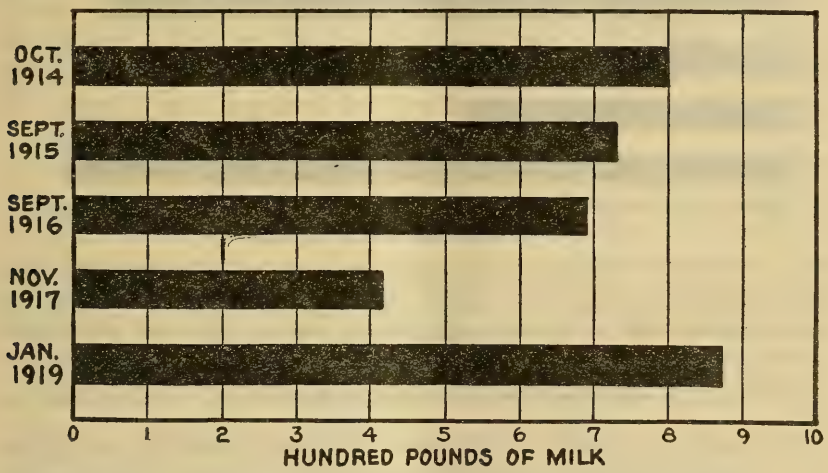

FIG. 1.—Influence of the length of the dry period on the subsequent milk yield in the case of cow 17. The columns represent the pounds of milk given in the first clear calendar month after calving in the years indicated. Before calving in the years 1914 to 1917, inclusive, this cow was fed the routine ration for dry cows at Beltsville; her dry periods averaged 44 days. Before calving, in December, 1918, she was given a dry period of 122 days and fed approximately as in her previous dry periods.

It is well known that animals are capable of storing up large quantities of nutritive material in times of plenty and using these stores in times of stress. The effect of the feed on milk secretion, therefore, often may be long delayed and rather complicated. It is not at all impossible that the effects of a deficient ration supplied in one lactation period may not show themselves until the subsequent period or even later.

Figures 1 and 2 give graphically the histories of two cows which were brought to the Beltsville farm some years ago and fed and treated according to the usual routine. The milk yields fell off very

noticeably during the routine treatment. After several years of the routine treatment cow 17 was given an unusually long dry period before calving, and cow 201, a more liberal ration for some weeks before calving. In both cases the subsequent milk yields were markedly increased. (See p. 13.)

The increase in the milk yields of these cows is due in the one case to the more liberal ration supplied before the calf was born; and in the other to the long dry period with a supermaintenance ration. The rations fed after calving bore about the same relation to the milk yield as they had in previous years. It may be added that the milk yield for the first few weeks of lactation is not very closely dependent on the contemporaneous food supply (2).

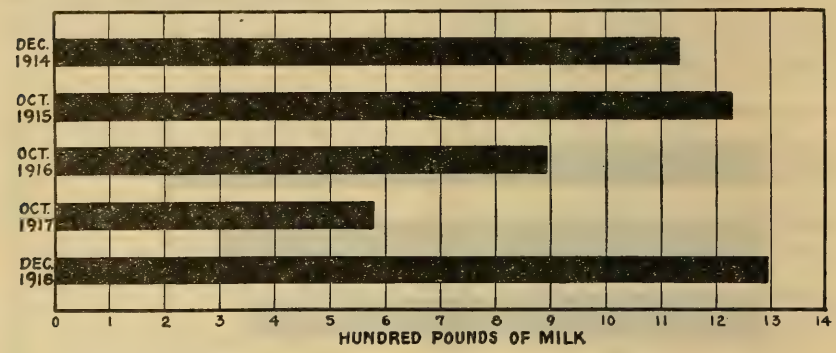

FIG. 2.—Influence of the length of the dry period and of the ration fed during that period on the subsequent milk yield in the case of cow 201. The columns represent the pounds of milk given in the first clear calendar month after calving in the years indicated. Before calving in the years 1914 to 1917, inclusive, this cow was fed the routine ration for dry cows at Beltsville; her dry periods averaged 50 days. Before calving in December, 1918, she was given a dry period of 78 days, and during the last 40 days of this period was fed a much more liberal ration than the previous one. (See pp. 13 and 14.)

The course of events which these two cows illustrate is typical. Several similar histories could be presented. Indeed, it has been the rule on this farm that greatly increased milk yields were obtained when cows from the general herd were dried off two months or more before they were due to calve and fed liberally during the dry period. Cows 17 and 201 were selected as examples, not because the downhill course of their milk yields on the routine treatment was particularly rapid or the subsequent recoveries particularly marked, but simply because they had been freer from disease and from disturbing experiments during their stay at Beltsville than others which might have been selected. It is, therefore, a very moderate statement of the case to say that average and high-producing cows often do not maintain anything like their optimum milk yield when they are bred to calve once a year and fed for several years approximately according to the most liberal of the American feeding standards, even

though they may get a little pasture in addition.[4] Under this treatment the milk yield may be reduced, after a few years, to less than half the optimum; and when it has been so reduced it may be very greatly increased by liberal feeding during a 2-months' dry period.

A point of great interest to be noted in the history of cow 201 is the length of time which it took for the full effect of the routine method of feeding to become apparent. The milk yield did not reach its lowest point until she had been on the farm for four years.

NATURE OF THE DEFICIENCY IN THE ROUTINE RATIONS FED AT BELTSVILLE.

It is probable that the rations fed at Beltsville were not deficient in a general sense, but deficient only in one or a few particular constituents necessary for milk secretion. The cows were kept in good general condition, which seems to indicate that they received enough of the energy-yielding portion of the ration. The recent very interesting work of Forbes (5) indicates that cows milking liberally may often receive insufficient calcium and phosphorus in their rations. The experiments reported in this bulletin were directed toward throwing more light on that question.

There is no doubt that a cow's milk yield may be markedly influenced by the nutriment which she receives during 6 or 8 weeks before her calf is born. The experiments to be reported have, therefore, been confined to the influence of the ration fed during this period on the subsequent milk yield; and, for the reasons that follow, the phosphorus fed during the dry period has been varied rather than the calcium.

The results of certain metabolism experiments in which the calcium and phosphorus balances have been followed—particularly those of Forbes (5) and Hart (8)—seem to show that calcium and phosphorus metabolism are largely independent of each other. In these experiments, however, the calcium and phosphorus balances were not followed for more than 20 days successively. There is no reason to doubt the figures that have actually been obtained, and it is very likely that a cow may lose 200 or 300 grams of calcium while remaining in phosphorus equilibrium. But it is doubtful whether the metabolic independence of the two elements ever goes much further than this. In a recently published article this question was discussed in some detail, and it has been pointed out that the weight of evidence obtained from carcass analyses is strongly against the view either that the ratio of calcium to phosphorus in bone is subject

[4] Our evidence shows only that cows are not kept up to their optimum milk yield when fed the protein and total nutriment required by the standards in the form of the amounts of grain, hay, and silage used on the Beltsville farm. The reader must judge for himself how closely this method of feeding approaches what is typical throughout the country.

to more than very small variations or that the concentration of either of these elements contained in any of the soft tissues undergoes more than insignificant changes. Evidence has also been adduced to indicate that calcium assimilation in cows is likely to be seriously interfered with for a period of at least eight days by the mere collection of their urine and feces by attendants as practiced in the experiments of Forbes, of Hart, and of ourselves (13).

It is likely, therefore, that any considerable deficiency of either calcium or phosphorus in the rations of a milking cow will bring about the loss of both elements from the animal's bones if continued for more than two or three weeks, and that a cow which has suffered from the lack of either during any considerable part of her lactation period will find herself depleted in both when she reaches the end of that period.

In recently published articles from this laboratory (12) (13) it has been shown that the phosphorus content of the blood plasma of cows is highly variable, and that it is likely to be low in the plasma of the Beltsville herd toward the end of their periods of pregnancy. This suggests that the cows of the Beltsville herd usually reach the end of their lactation period with their phosphorus stores depleted, and that the rations fed during the dry period are not sufficient to restore them. For the reasons which have been given it is likely that the calcium stores of the Beltsville cows are also depleted during their lactation periods, and that neither the calcium nor the phosphorus stores can be restored to their proper level during the dry period unless the cows are fed rations which make it possible for them to assimilate liberal quantities of both elements.

In the articles just mentioned, certain other facts regarding calcium and phosphorus metabolism were brought to light. It was shown that the concentration of calcium in cows' blood plasma is much more constant than that of phosphorus. It is usually easy to raise the concentration of plasma phosphorus by increasing the amount of phosphorus in the rations—either by feeding more grain or by adding sodium phosphate to the ration. But the changes, brought about in the concentration of plasma calcium by analogous procedures or by any other influences that we have encountered so far, are comparatively insignificant and usually fall within the limits of error of our determinations.

It has seemed likely, therefore, that changing the amount of phosphorus in the ration would have more immediate and easily determinable effect on the changes which go on in a cow's udder shortly before her calf is born than changing the amount of calcium. The experiments herein reported were planned with this idea in mind. But it was essential that both the control and the experimental ani-

mals should have plenty of calcium in their rations, and therefore all received alfalfa hay in quantities which it was hoped would provide sufficient calcium.

The details of the experimental procedure and the results obtained are given in the description and tables at the end of the article.

The experiments consisted essentially (*a*) in drying cows off about 60 days before they were due to calve, (*b*) in feeding the controls a certain basal ration, (*c*) in feeding the others the same basal ration, giving grain and hay on alternate days and adding sodium phosphate to the grain, and (*d*) in following the milk yields from the tenth to the fortieth day after calving.

Some of the animals used in the experiments were from the general herd, and had previously been fed approximately according to the Savage feeding standard. Others had been on test during the year preceding the experiments, and had been fed much more liberally. In the case of the animals from the general herd (see Tables 1 and 2) the alternated feeding with phosphate had a very favorable influence on the subsequent milk yield; but in the case of those which had been on test (Table 3), the effect was insignificant. This indicates that the rations fed to the general herd were deficient in one or both of the principal bone-building elements.

The results show that the effect of the alternated feeding with phosphate on the subsequent milk yield will depend on the previous history of the cows as well as on the amount of phosphorus contained in the basal ration. It follows that the quantitative results of the experiments are significant only for the special conditions under which they were carried out. They might be entirely different in a herd whose previous history had been different, or with a basal ration which contained a different amount of phosphorus.

The attempt has been made, however, to get an approximately quantitative idea of the increase in milk yield produced by the phosphate feeding under the conditions of experimentation used with the cows of the general herd. For this purpose, only those animals have been considered which figure both as controls and as experiment animals and whose histories are given in Table 1. The method and results used in this attempt are given in Table 8 with its appended comment and in figure 3. The animals gave, on the average, 37.9 per cent more milk after the phosphate feeding than would have been expected from their previous performance.

The milk yield from the tenth to the fortieth day after calving has been taken as the most important measure of the effect produced by the alternated feeding with phosphate during the preceding dry period. But certain other aspects of the effect produced by this treatment have also been studied.

Both the animals on the experimental feeding and those used as controls were weighed from time to time. We do not wish to lay too much stress on the results obtained, because the manner in which an animal gains weight in the period of a month or so before it calves depends almost as much on its previous history as on the ration fed at the time. The results in question are given in Tables 4, 5, 6, and 7. They are rather irregular, but indicate, on the whole, that the animals on alternated feeding with phosphate made somewhat better gains than the controls.

In a previous publication from this laboratory (13) a balance experiment was described in which the animals received alternated rations with phosphate for a part of the time. The alternated feeding with phosphate had no perceptible effect on the amount of urine or feces voided or on the water content or consistency of the feces.

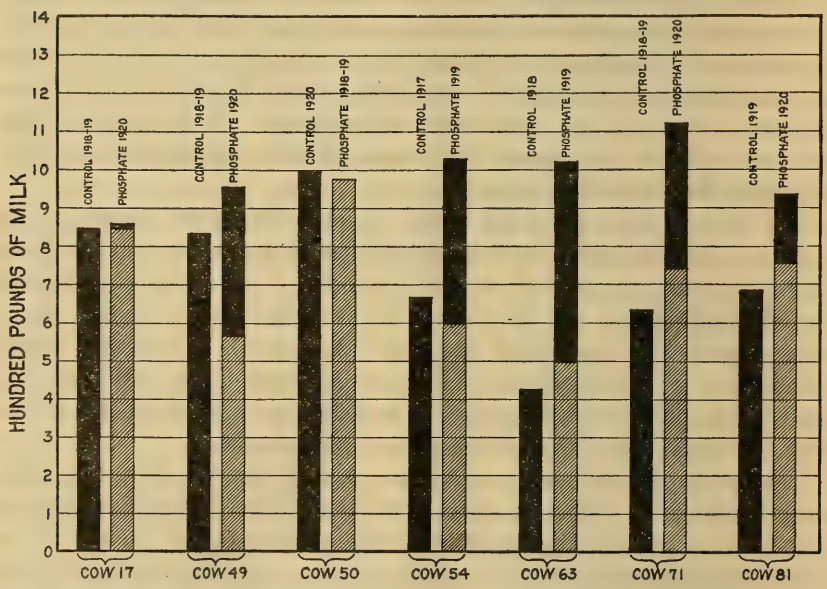

FIG. 3.—Comparison of milk yields of cows from the general herd after control and phosphate feeding. The columns show the amounts of milk given in 30 days soon after calving; the lighter portions of the columns show the amounts of milk to be expected after the phosphate feeding, using the yields after the control feeding as a basis, and taking into account the facts that some of the animals aborted and that the younger ones would show the increase normally occurring with the second calf (see pp. 24 and 25) during the experimental feeding.

We have the impression that the increase in size of the udder which occurs before calving has generally appeared earlier and has been more marked in the animals which have received the phosphate than in the controls. There have, however, been exceptions to this rule, and we do not feel inclined to insist very strongly upon it. We realize keenly the difficulty of judging accurately where no exact measurements are taken.

DISCUSSION OF RESULTS.

Our results indicate that the milk yield of the general herd at Beltsville has been reduced by an insufficiency either of calcium or of phosphorus, or of both, in the rations, in spite of the facts that these contained more than the average proportions of both calcium and phosphorus and were fed in the amounts required according to the feeding standards. We think it is still an open question whether calcium or phosphorus has been the element chiefly lacking, and whether the rations could be improved from the standpoint of mineral nutrition by varying the proportions of the different feeds used. Work aimed to throw light on these problems is now being carried out here. In the meantime, however, it seems worth while to consider what the knowledge already at hand indicates ought to be done.

Table 1 contains the cases where a cow s record after the phosphate feeding is compared with a previous record of her own made after a period on the basal ration. It will be noted that in most of these cases the basal ration was fed before the first calf was born. The results as given in this particular table, therefore, are chiefly evidence for the view that the heifers received insufficient calcium or phosphorus in the rations supplied to them before they had their first calves.

We believe that this was the case, and we shall later discuss the rations supplied to the heifers which had never had calves. But the records for the general herd indicate that, under the Beltsville routine, the animals never recovered from the mineral shortage which made itself evident in the first lactation period.

The evidence from the records which indicates this may be summed up as follows: In the case of the animals born at Beltsville and kept under the routine treatment there was no tendency for the milk yield to rise after the first lactation period to the extent that it did in the cases of cows 54, 63, 71, and 81, shown in Table 1. The rise as between the first and subsequent lactation periods was approximately that which would be expected from the data collected by Pearl and Patterson (14) and by the Holstein and Guernsey breeding associations. In the case of animals brought to the farm from other places and kept under the routine treatment, there was frequently a tendency for the milk yield to fall off more rapidly than it should with advancing age, as in the cases of cows 17 and 201, figures 1 and 2.

As many of the cows which received the alternated rations with phosphate received a basal ration somewhat lower than that fed to the general herd during their dry periods, it is fair to compare the milk yields of these two sets of animals. Cows 49, 54, 71, and 81 may be taken as representing the effects of the phosphate feeding in the

case of grade Guernseys. In a period of 30 days soon after calving, these animals gave 1,009 pounds of milk on the average. Their records may be compared with those of the other grade Guernseys of the herd, selecting lactation periods later than the first and in which there was no suspicion of abortion or other disturbing disease, and using the best month's milk yield in each lactation period as the figure to be compared with that given above. There are 4 animals with a total of 8 lactation periods available for the comparison, and the average best month's milk in the 8 lactation periods was 660 pounds. As the grade Guernseys available for this comparison were rather few, the same calculation was made for the grade Jerseys. There are 16 animals with 52 lactation periods available in this case. The average best month's milk is 722 pounds. The grade Holsteins are not sufficiently numerous to give figures of any value.

No cow among the grade Jerseys and Guernseys of the general herd has ever surpassed the 30-day record of cow 71. In only one case has the average 30-day record given for cows 49, 54, 71, and 81 after the phosphate feeding, been surpassed, namely, with a best month's milk yield of 1,041 pounds given by one of the grade Jerseys. In only five cases has the lowest 30-day record among these four cows been surpassed, namely, by best month's milk yields of 1,041, 988, 987, 1,004, and 943 pounds, respectively.

The results show, therefore, that the cows of the general herd at Beltsville suffered from an insufficiency of either calcium or phosphorus, or both, in their rations throughout their lives, both before their first calves were born and afterwards. The following shows a little more in detail than has been done heretofore how they were fed.

The young stock generally received milk until the animals were six months old or more. The feeding of grain, hay, and silage, however, was started before the end of the first month and gradually increasing quantities of these feeds were given until at the end of six months the calves were taking 3 pounds of grain, 3 pounds of legume hay, and 10 to 20 pounds of corn silage. After they were taken off milk the calves were usually fed 3 pounds of grain, 3 pounds of legume hay, and as much corn silage as they would clean up. The grain mixture most used was grain mixture E. If they ate 25 pounds of corn silage daily, which may be taken as a fair average, this ration would supply 0.94 pound digestible protein daily and 8.16 pounds total digestible nutriment. This is approximately the protein requirement given in the Wolff-Lehmann feeding standards for growing dairy cattle and somewhat more than the requirement for total nutriment (10).

The manner in which the cows were fed and treated subsequent to the birth of their first calves has already been discussed at some length (pp. 1 to 3). It is only necessary to add a word about the actual amounts of grain, hay, and silage given. The manner in which the mature dry cows were fed has already been given (p. 2). The mature milking cows were generally fed 1 pound of grain mixture B or C to each 3 pounds of milk given, 6 to 8 pounds of legume hay, and as much corn silage as they would clean up. They usually gave about 25 pounds of milk a day when they were fresh and at this period they commonly got 8 pounds of grain mixture B, 8 pounds of legume hay, and 30 pounds of corn silage. They usually got a little thin with the progress of their lactation and were then fed somewhat more grain in proportion to the milk yield. In the course of the year, as has already been stated, they got a little more protein and total nutriment than is required by the Eckles or Savage feeding standards.

The bone-building elements can probably be supplied in sufficient quantity in two different ways—either by feeding the ordinary materials much more liberally than the feeding standards require or by adding calcium and phosphorus in the form of inorganic salts directly to the rations. We are confident that the latter method will finally be adopted and will effect a great saving in the cost of producing milk.

But so radical a change in feeding practice ought, perhaps, to be introduced slowly and with caution; the more conservative dairyman will probably prefer to keep to the ordinary farm feeds until the effects of feeding inorganic salts of calcium and phosphorus have been more fully worked out by the experiment stations.

Our experience at Beltsville indicates that with many cows a liberal ration fed for 4 to 6 weeks before calving easily pays for itself through the increased flow of milk in the subsequent lactation period, and we think that there are many cows throughout the country which are far more valuable than their owners suppose them to be. Those dairymen who have been feeding their animals according to the standards or less should try giving each cow a period of two months dry and feeding her during that period three or four times the protein and two or three times the total nutriment required for maintenance. The feeds used should contain plenty of calcium and phosphorus—legume hay and a liberal proportion of bran and cottonseed or linseed meal. If dairymen find that the milk yield of any of their cows is doubled by this process, they will run no risk of reducing their profits by feeding those cows even 50 per cent more

nutriment in the course of the year than the feeding standards call for.[5]

There is one other aspect of the case which must be discussed. Quite apart from the question of the feed cost per pound of milk when a cow's yield is reduced by feeding a ration deficient in one or more necessary constituents, is the question of the effect of this process on her capacity to resist disease. The Beltsville herd has suffered severely in the last three years from contagious abortion. The relation between the incidence of this disease and the manner in which the cows have been fed is being carefully studied at present, and the results of this study will be reported later. The results already obtained, however, are sufficient to justify a strong suspicion that abortion has occurred more frequently among the animals that were less adequately fed. But, whatever the final results of this study may be, it is obviously bad practice to allow a cow to deplete her body stores of important materials for long periods of time, even though milk may thereby be temporarily more economically produced. The ideal method is clearly to keep the yearly supply of raw materials in the food equal to the demand for milk production.

SUMMARY.

Feeding cows for several years according to the commonly accepted standards with little or no additional pasture, has resulted in their milk yield being reduced much below the optimum. The condition of reduced milk yield so brought about may be corrected by giving the animal a dry period of two months, and feeding during that period a ration containing legume hay and grain with a high phosphorus content and with three or four times the amount of protein required for maintenance, and two or three times the total nutriment. The milk yield in the subsequent lactation period may sometimes be doubled by this treatment.

In the case of cows of which the milk yield has been reduced by several years' standard feeding, a greatly increased yield can be brought about by feeding "alternated rations with phosphate" during the dry period. This is taken to mean that the ordinary rations are more likely to be deficient in one or both of the principal bone-building elements than in any other constituent.

[5] Feeding cows heavily before they calve, of course, introduces the risk of milk fever. But if this disease is properly treated, the mortality is not high, and there are apparently no enduring bad effects. A well-managed dairy farm should be equipped for dealing with milk fever. Our experience at Beltsville shows that the risk even of the appearance of the disease is not very great. In the last five years there have been something over 30 cases of cows fed two to four times the maintenance requirement of protein and total nutriment before they calved, and milk fever has appeared only twice. One of these cases was in a young cow, but was mild; the other was in a cow 15 years old.

DESCRIPTION OF EXPERIMENTS, PROTOCOLS, AND TABLES.

EFFECTS, ON MILK YIELD, OF LIBERAL FEEDING DURING DRY PERIOD.

Cow 17, a grade Jersey, was born in 1909 and brought to the Beltsville farm in 1912. The protein and total nutriment contained in her rations during the years 1914, 1915, 1916, and 1917 were calculated and compared with the quantities required for her maintenance and for her milk and fat yield according to the Savage standard (9), and it was found that she received on the average a surplus of about 10 per cent of protein and about 2 per cent total nutriment. It may be considered, therefore, that she was fed as nearly according to this standard as is possible under any ordinary conditions. She was on pasture for only 7 days during the four years under consideration. She had a calf toward the end of the summer of each year; the 1917 calf was born six weeks ahead of time, but it survived and was alive and well in June, 1920. The other three calves were all born at term. Her dry periods were 44 days on the average.

In 1914 she gave 5,709 pounds of milk; in 1915, 5,121 pounds; in 1916, 5,056 pounds; in 1917, 4,693 pounds; and in 1918, 2,569 pounds.[6] In 1918 she was given a dry period of 122 days, with approximately the same ration as in previous dry periods. She calved December 11, 1918, and her milk yield for 1919 rose to 5,578 pounds.

During her dry periods in 1914, 1915, and 1917, she was fed 4 pounds of grain mixture B, 4 pounds of legume hay, and 30 to 35 pounds of corn silage. During her dry period in 1916 she received 4 pounds of grain mixture B, 3 pounds of oat hay, 28 pounds of corn silage, and had 7 days on pasture. During the last 53 days of her 1918 dry period she was fed 4 pounds of grain mixture C, 4 pounds of legume hay, and 30 pounds of corn silage. Her milk yields for the first clear month after calving in each of the five years under consideration were as follows: October, 1914, 799 pounds; September, 1915, 731 pounds; September, 1916, 690 pounds; November, 1917, 416 pounds; and January, 1919, 873 pounds.

The milk yield for the first six weeks after calving is not markedly influenced by moderate changes in the feed supplied (2), and the rations given in the months mentioned above were so nearly equivalent that they could not have produced the observed differences in the milk yield. These are to be attributed, therefore, to the nutritive condition of the cow in her dry periods. The large yield for January, 1919, is the result of the long dry period with a ration considerably above the maintenance requirement.

Cow 201, a purebred Holstein, was born March 13, 1905, and brought to Beltsville in 1912. The protein and total nutriment con-

[6] This very low yield is partly explained by the facts that the cow aborted in 1917 and that she had an unusually long dry period in 1918.

tained in her rations during the years 1914, 1915, 1916, and 1917 were calculated and compared with the quantities required for her maintenance and for her milk and fat yield according to the Savage standard, and it was found that she received, on the average, a surplus of about 8 per cent protein and about 9 per cent total nutriment. She was on pasture for 46 days during the four years under consideration. She calved normally in the autumn of each year. Her dry periods were 50 days on the average.

In 1914 she gave 12,182 pounds of milk; in 1915, 8,269 pounds; in 1916, 7,224 pounds; in 1917, 5,708 pounds; and in 1918, 4,796 pounds. In 1918, she was given a dry period of 78 days, and, during the last 40 days of this period, was fed a much more liberal ration than during her previous dry periods. She calved October 30, 1918, and her milk yield for 1919 rose to 8,711 pounds.

During her dry periods in 1914, 1915, 1916, and 1917 she was fed approximately the same rations as those fed to cow 17 in her corresponding dry periods. During the last 40 days of her 1918 dry period she was fed daily 11 pounds of grain mixture C, 11 pounds alfalfa hay, and 26 pounds corn silage. Her milk yields in pounds for the first clear month after calving in each of the five years under consideration were as follows: December, 1914, 1,138 pounds; October, 1915, 1,230 pounds; October, 1916, 896 pounds; October, 1917, 579 pounds; December, 1918, 1,293 pounds.

For the same reasons as have been given in the case of cow 17, the greatly increased milk yield after the 1918 calving is to be attributed to the more liberal ration fed in the 1918 dry period. It should be mentioned that this cow was milked three times a day during December, 1918, and only twice in the other months above recorded. But the increase in milk yield to be expected from this change in treatment has been much studied at Beltsville; it could hardly have been more than 10 per cent in a case such as that under consideration. The actual increase as between October, 1917, and December, 1918, was more than 120 per cent.

EFFECTS, ON MILK YIELD, OF FEEDING PHOSPHATE WITH ALTERNATED RATIONS DURING DRY PERIOD.

These experiments may be generally described as follows: Cows were dried off about two months before they were due to calve and were fed, during their dry periods, a basal ration containing 3 to 6 pounds of grain, 4 to 5 pounds of alfalfa hay, and 30 pounds of corn silage. Half of the animals were used as controls and were fed the basal rations without supplement. The others received the same basal rations supplemented with sodium phosphate, the grain and hay of the rations being fed on alternate days. In many cases the same

nimal served as a control one year and as an experiment animal the next year. In a typical experiment an animal would receive daily for 60 days before calving 3 pounds of grain mixture C, 4 pounds alfalfa hay, and 30 pounds corn silage. The next year she would receive in the corresponding period the same average daily quantities of the same feed, but instead of receiving equal amounts of all the feeds every day, she would receive on one day no grain, 8 pounds of alfalfa hay, and 30 pounds corn silage, and the next day 6 pounds of grain with sodium phosphate added to it, no hay, and 30 pounds of corn silage. For the sake of brevity the first procedure will be spoken of as the "control feeding," the second as the "experimental feeding" or the "alternated feeding with phosphate."

The animals which received the phosphate were fed alternated rations, as above described, with the idea of separating to some extent the calcium and phosphorus compounds in the intestinal tract. There is a good deal of evidence to show that the absorption of phosphorus from the intestinal tract may be hindered by the simultaneous presence of calcium compounds (1), (4), (7). As the hay contains most of the calcium of the rations, and the grain most of the phosphorus, the experimental animals received an excess of calcium one day and an excess of phosphorus the next. When the average daily ration was 6 pounds of grain mixture CP, 4 pounds alfalfa hay, and 30 pounds corn silage, they received about 61 grams of calcium and 17 grams of phosphorus on the days when they were fed hay; and about 16 grams of calcium and 50 grams of phosphorus on the grain days.

After calving, the controls and experiment animals were fed alike or according to their milk yields. As the milk yield for the first five or six weeks after calving is not much influenced by small changes in the contemporaneous food supply (2), we have not thought it necessary to give a detailed account of how the cows were fed during this period.

The milk and fat yields of the control and experiment animals were followed for the first 40 days after calving, and, as a rule, the milk produced from the tenth to the fortieth day after calving was taken as a measure of the effect of the alternated feeding with phosphate. In many cases the body weights of the animals were also followed during the periods when they were on the control or the experimental feeding.

It was decided to use sodium phosphate as the mineral supplement, partly in order to study the effects of phosphorus as distinguished from calcium, partly because the phosphates of sodium are much more soluble in neutral solutions than any of the phosphates of calcium, and it was judged that feeding the more soluble salts would produce the maximum effect of the phosphorus on metabolism. Di-

sodium phosphate (Na_2HPO_4) was selected because it is the most nearly neutral of the various sodium salts. A very pure preparation of this compound, containing 9 to 12 molecules of water of crystallization,[7] can be obtained commercially at about $100 per ton.

Sodium phosphate has been fed in only a few of the numerous phosphate-feeding experiments which have been conducted in the past. Gouin and Andouard (6) worked with it to some extent, but they gave no information in regard to the particular sodium phosphate used or in regard to its water content. If we understand them right, their doses were very small in comparison to those which we finally used. We began with doses of 4.5 grams of phosphorus as di-sodium phosphate daily, and finally gave doses of 24 grams without producing any noticeable digestive disturbances.

In deciding on the basal ration to which the phosphate was to be added we were largely influenced by the fact that the dry cows at Beltsville had previously been fed, as a matter of routine, a ration consisting of 4 pounds grain,[8] 4 pounds legume hay, and 30 pounds corn silage.

This ration carries decidedly more than enough protein and total nutriment to provide for the maintenance of a 1,000-pound cow, according to the Haecker and Savage standards (9); and according to the results obtained by Eckles (3), the surplus should be sufficient to provide for the development of the unborn calf. Using a slightly less liberal feed for the basal ration made it possible to compare the performance of the cows fed phosphate in addition with that of the general herd. In several cases, however, a somewhat more liberal ration was used both for the control and for the experimental animals.

Alfalfa was selected as the hay to be used, partly on account of its high calcium content and partly because it had been used at Beltsville in the past as often as anything else.

The experiments fall into two general classes: First, those on animals which had been fed for some years previously according to the routine used for the general herd; and, second, those on animals which had been on test and which, for at least a year preceding our experiments, had been fed much more liberally than the general herd. In the first class there are two smaller groups. Group 1 consists of seven experiments where the same animal served in one year as control and in another as experiment. Group 2 consists of experiments in which the records of animals on the phosphate feeding were

[7] The salt crystallizes with 12 molecules of water, but loses a considerable part of its water of crystallization readily on exposure to air. As obtained commercially, therefore, it generally contains less than 12 molecules of water.

[8] The grain mixture fed has been varied from time to time. Those most frequently used were grain mixtures B and C. The protein, total nutriment, and mineral content of these are fairly typical for all the other mixtures.

compared with those of other approximately similar animals used as controls.

The data in the case of the animals which had been on test are rather complicated. In our experiments all these animals were dried off 60 days or more before they were due to calve and were fed during this period on a basal ration of 3 pounds grain mixture D, 5 pounds alfalfa hay, and 30 to 35 pounds corn silage. The controls received this ration fed in the usual way and without any supplement. The others received grain and hay on alternate days and with phosphate added to the grain. It would be possible to compare the experiment animals directly with the controls in this series, but as they are not exactly comparable and as the cases are few we have thought it better to take into account the past records of both controls and experiment animals. We have, therefore, compared the performance of each animal, after either control or phosphate feeding, with her performance in the preceding year and determined whether the phosphate or control performances compare the more favorably with the preceding performance of the same animal.

For several years before the experiments began the cows from the general herd, of which the histories are tabulated in Tables 1 and 2, were fed approximately according to the Savage standard. They received on the average about 0.25 pound protein and 1 pound total nutriment more daily than this standard calls for. The building of the calf annually is not taken account of in this calculation, but the yearly 91 pounds protein and 365 pounds total nutriment received over and above what the standard calls for should have provided sufficiently for this process, according to Eckles's results (3).

The manner in which the test cows were fed contrasts strongly with the above method. During the year in which they were on test and actually milking these animals received a daily average surplus of 1 to 1.5 pounds protein and about 4 pounds total nutriment. For a number of weeks before they calved they received the enormous daily surplus of about 4 pounds protein and 16 pounds total nutriment. In other words, the ration fed before calving in preparation for the test contained about six times as much protein and about three times as much total nutriment as is required for maintenance. In the course of a year, taking into account the dry period before going on test, these animals received about 100 per cent more protein and about 50 per cent more total nutriment than is called for by the Savage standard.

It will be noted that the character of the experiments has made it necessary to keep the animals under observation for periods of more than a year, and to use the milk yield as a measure of the results to be studied. In the course of a year innumerable small things, which

are quite beyond experimental control but which might have some influence on milk yield, happen to a cow—weather changes and small disturbances in health and appetite are examples of such incidents. To report them, even to the extent to which they have been recorded in our notes, would be quite impracticable on account of the space required. We have, therefore, given only such features of the histories of the cows as might have an influence on the milk yield of the same general order of magnitude as the differences which have commonly been observed as the result of the phosphate feeding.

The manner in which the animals were fed before calving in our experiments is given below, and the tables give such data regarding the experiments as can be conveniently tabulated.

RATIONS GIVEN ANIMALS BEFORE CALVING.

ANIMALS FROM THE GENERAL HERD.

Cow 17, 1918.—September 25 to October 18, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. October 19 to December 11, 4 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 17, 1919–20.—November 26, 1919, to February 14, 1920, alternated rations with daily average of 3¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage. February 15 to March 29, 1920, alternated rations with daily average of 4¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 21, 1918.—August 28 to November 30, alternated rations with daily average of 6 pounds grain mixture CP_1, 5 pounds alfalfa hay, 30 pounds corn silage.

Cow 49, 1918.—October 31 to December 1, 4 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. December 2 to 25, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 49, 1919–20.—December 12, 1919, to January 14, 1920, alternated rations with daily average of 4¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 50, 1918.—October 2 to December 20, alternated rations with daily average of 5 pounds grain mixture CP_1, 4 pounds alfalfa hay, and 30 pounds corn silage. From October 4 to 9, 85 grams calcium carbonate were added daily to the silage on the days when hay was fed; from October 10 to December 20, 158 grams.

Cow 50, 1920.—April 2 to June 3, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 54, 1917.—March 14 to May 14, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 54, 1919.—May 8 to June 2, alternated rations with daily average of 3 pounds grain mixture CP_1, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 59, 1917.—October 26 to December 26, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 63, 1917–18.—December 1, 1917, to February 1, 1918, 3 pounds grain mixture C, 8 pounds corn stover, 30 pounds corn silage.

Cow 63, 1919.—February 3 to March 10, alternated rations with daily average of 3 pounds grain mixture CP_1, 4 pounds alfalfa hay, 24 to 30 pounds

corn silage. March 11 to 28, 3 pounds grain mixture C, 4 pounds alfalfa hay, 24 pounds corn silage; rations not alternated. March 29 to April 25, same as for February 3 to March 10.

Cow 64, 1918–19.—December 19, 1918, to January 5, 1919, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. January 6 to February 6, 1919, 6 pounds grain mixture C, 5 pounds alfalfa hay, 30 pounds corn silage.

Cow 67, 1918.—April 1 to 20, alternated rations with daily average of 3 pounds grain mixture CP_2, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 70, 1918–19.—October 19, 1918, to January 27, 1919, alternated rations with daily average of 3 pounds grain mixture CP_1, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 71, 1918.—September 25 to December 1, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. December 2 to 11, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 71, 1919–20.—December 20, 1919, to February 20, 1920, alternated rations with daily average of 3¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage. February 20 to March 1, 1920, alternated rations with daily average of 5¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 81, 1919.—February 24 to April 24, 1919, 3 pounds grain mixture E, 3 pounds alfalfa hay, 30 pounds corn silage, 5.7 grams calcium as calcium chlorid daily.

Cow 81, 1920.—February 13 to April 6, alternated rations with daily average of 3¼ pounds grain mixture CP, 3 pounds alfalfa hay, 30 pounds corn silage.

Cow 213, 1918.—January 1 to February 6, 5.6 pounds grain mixture C, 3 pounds soy-bean hay, 8 pounds corn stover, 25 pounds corn silage.

Cow 214, 1918.—March 28 to May 6, alternated rations with daily average of 3 pounds grain mixture CP_2, 4 pounds alfalfa hay, 30 pounds corn silage. May 7 to 15, alternated rations with daily average of 5 pounds grain mixture CP_2, 4 pounds alfalfa hay, 30 pounds corn silage. May 16 to 27, alternated rations with daily average of 5 pounds grain mixture CP_1, 4 pounds alfalfa hay, 30 pounds corn silage.

ANIMALS WHICH HAD BEEN ON TEST DURING THE YEAR PRECEDING THE EXPERIMENTS.

For a month or so before they calved previous to the test lactation period these animals were fed daily rations of from 8 to 18 pounds of grain mixture F, 10 to 16 pounds alfalfa hay, and 24 to 30 pounds corn silage. The grain mixtures fed contained more protein and ash than either grain mixture C or D. The rations supplied a great excess of both protein and total nutriment above the maintenance requirements.

After they had finished their tests, these animals were dried off about two months before they were due to calve. Cows 227, 232, and 240 were selected as controls and were fed 3 pounds grain mixture D, 5 pounds alfalfa hay, and 30 pounds corn silage for 60 days before calving. Cows 228, 229, and 248 served as experimental animals. For 60 days before calving they were fed alternated rations with a daily average of 3½ pounds grain mixture DP, 5 pounds alfalfa hay, and 30 pounds corn silage.

CONDENSED HISTORY OF THE EXPERIMENTAL ANIMALS.

TABLE 1.—*Animals from the general herd used both as experiments and controls.*

No. of animal.	Date of birth.	Breed.	Date of calving.		Days dry.		Milk yield.[1]		Fat yield.[1]	
			After control feeding.	After phosphate feeding.	Control period.	Phosphate period.	After control feeding.	After phosphate feeding.	After control feeding.	After phosphate feeding.
					Days.	*Days.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
17	1909.	Grade Jersey..	Dec. 11, 1918	Mar. 29, 1920	122	122	847	858	33.9	33.5
49	Oct. 22, 1914	Grade Guernsey.	Dec. 25, 1918	Jan. 14, 1920	71	36	831	953	40.7	43.8
50	Oct. 25, 1914	Grade Holstein	June 3, 1920	Dec. 20, 1918	73	98	995	972	38.8	38.9
54	Jan. 22, 1915	Grade Guernsey.	May 14, 1917	June 2, 1919	First calf.	61	669	1,027	24.1	34.9
63	Oct. 17, 1915	Grade Holstein	Feb. 1, 1918	Apr. 25, 1919	..do..	103	422	1,018	15.5	34.1
71	July 15, 1916	Grade Guernsey.	Dec. 11, 1918	Mar. 1, 1920	..do..	60	632	1,121	29.1	49.3
81	Feb. 19, 1917	.....do.....	Apr. 24, 1919	Apr. 6, 1920	..do..	44	685	936	26.0	42.1

[1] The figures given in these columns represent the number of pounds of milk and fat given from the tenth to the fortieth day after calving, except in the case of cow 54. In this case it was necessary to take the figures for the yields from the eighteenth to the forty-eighth day after calving, as the daily milk records from the tenth to the seventeenth day in 1917 had been lost.

The following comments are made on the animals in Table 1:

Cow 17.—This animal gave very little more milk after the phosphate feeding than after the control feeding. She had a long dry period in both cases. It seems likely that the long dry period enabled her to restore any insufficiency of bone material which may have existed at the beginning of the experiment. She had a uterine infection after the experimental feeding, which may have reduced her milk somewhat in the experimental period.

Cow 49.—This animal aborted during the period of phosphate feeding 39 days before term. The abortion greatly shortened her dry period on the phosphate feeding and prevented her receiving the more liberal grain ration which she had eaten for 23 days before calving during the control period. In the general herd, abortions 5 weeks or more before term have decreased the first two months' milk yield from 30 to 50 per cent. We have no way of accounting for the increased milk which was given in this case after the abortion, except as the result of the phosphate feeding.

Cow 50.—This animal was fed a much more liberal grain ration than the others in both the control and experimental periods. She "leaked" milk from her udder to a considerable extent through the experimental period, and she had a uterine infection after calving in the control period, which may have somewhat reduced her milk yield. She gave a little more milk in the control period than in the experimental period. The numerous disturbing circumstances make it difficult to interpret the results, but they seem to us to indicate that often the addition of phosphate will have little effect when the basal grain ration is as high as 5 pounds daily.

Cow 54.—This cow aborted during the phosphate feeding 28 days before term. Judging from the history of such cases in the general herd, her milk yield should have been about 10 per cent less than after the control feeding. We have no way of accounting for the actual increase except as the result of the phosphate feeding.

Cows 63, 71, and 81.—The remaining three animals of Table 1 were fed on the control rations before their first calves were born and on the experimental rations before their second calves were born. It is well known that heifers are likely to give more milk with their second than with their first calves; the average increase has been worked out by Pearl and Patterson (14) for Jerseys, and the department has figures obtained from the cow-testing associations for Guernseys and Holsteins. In Table 8 we have given the actual and expected increases; in calculating the expected differences we have in each case used the set of figures which would give the largest differences, in order to avoid any possible suspicion of favoring the results of the phosphate feeding. The milk yield of all three heifers increased after the phosphate feeding decidedly more than would be expected as the result of age alone. We have no way of accounting for the additional increases except as the result of the phosphate feeding.

TABLE 2.—*Animals from the general herd used only either as experiment or control animals.*

No. of animal.	Date of birth.	Breed.	Date of calving.	Days dry.	Milk yield.[1]	Fat yield.[1]
CONTROLS.						
				Days.	*Pounds.*	*Pounds.*
59	Aug. 10, 1915	Grade Holstein	Dec. 26, 1917	First calf	568	20.5
64	Oct. 18, 1915	do	Feb. 6, 1919	62	1,108	40.1
213	Sept. 26, 1915	Holstein	Feb. 6, 1918	First calf	742	26.7
EXPERIMENT ANIMALS.						
21	1907	Grade Jersey	Nov. 30, 1918	85	1,458	60.9
67	Dec. 29, 1915	Grade Holstein	April 20, 1918	First calf	753	26.3
70	April 22, 1916	Grade Guernsey	Jan. 27, 1919	do	588	28.3
214	Mar. 18, 1916	Holstein	May 27, 1918	do	1,554	46.8

[1] The figures given in these columns represent the number of pounds of milk or fat given from the 10th to the 40th day after calving.

The animals whose histories are tabulated in Table 2 were used in early experiments in which we were still feeling around for the conditions under which the effects of the phosphate feeding would stand out most sharply and in which the treatment of the subjects was not so carefully controlled as in the later experiments. The results, however, are in general accord with those of the later experiments, and it has seemed to us worth while to report them.

It would, perhaps, be fair to compare cow 59 with cows 67 and 70; cow 64 with cow 21; and cow 213 with cow 214. The figures for cow 59 represent approximately the average performance for the heifers of the general herd with their first calves. Cow 67 is a half sister of cow 59. The two animals have the same sire; the dam of 67 has a somewhat better record than that of 59. Cow 70 was selected in order to try the effects of phosphate feeding in an unfavorable case. Her mother had the poorest record of all the cows in the herd except two, and she herself was of unpromising appearance. Cow 64 was milked only twice a day; and cow 21 three times. The difference in the milk yields is, however, larger than is generally produced by this difference in treatment. Cows 213 and 214 were half sisters, both being daughters of the same sire. The dam of cow 213 had a decidedly better record than the dam of cow 214. Cow 213 was milked only twice a day, and cow 214 three times, but the difference in milk yields is very much greater than could be accounted for by this difference in treatment.

TABLE 3.—*Animals which had been on test during the year preceding the periods of control and phosphate feeding.*

CONTROLS.

No. of animal.	Date of birth.	Breed.	Date of calving.		Days dry.		Milk yield.[1]		Fat yield.[1]	
			Test period.	After control or phosphate feeding.	Before test period.	Control or phosphate feeding period.	Test period.	After control or phosphate feeding period.	Test period.	After control or phosphate feeding period.
					Days.	*Days.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
227	Aug. 2, 1915	Holstein.....	Apr. 18, 1918	Jan. 11, 1920	First calf.	137	1,674	2,019	61.8	83.8
232	Mar. 31, 1916	.....do.....	Nov. 29, 1918	Mar. 15, 1920	...do..	58	1,591	2,046	45.5	67.5
240	Nov. 10, 1914	.....do.....	Sept. 27, 1918	Feb. 9, 1920	59	112	1,876	1,881	64.2	80.9

EXPERIMENT ANIMALS.

228	Sept. 2, 1915	Holstein.....	Apr. 4, 1918	Dec. 30, 1919	First calf.	79	1,429	2,016	44.7	64.9
229	Nov. 8, 1915	.....do.....	May 28, 1918	Jan. 31, 1920	...do..	94	1,817	2,078	53.8	71.7
248	Mar. 15, 1916	.....do.....	Jan. 22, 1919	June 17, 1920	...do..	63	1,594	1,611	51.0	45.1

[1] The figures in these columns represent the milk and fat yields from the tenth to the fortieth day after calving, except in the case of cow 229. In her case they represent the milk and fat yields from the twentieth to the thirty-fifth day after calving multiplied by 2. It was necessary to take these figures instead of the usual ones, as she was sick for some days after calving in 1920, and suffered a severe cut in her rations, and she became sick again on the thirty-sixth day after calving.

It is not necessary to make any detailed comment on the results given in Table 3.

The differences in milk yield as between the cows fed phosphate and those fed the basal ration alone are so small as to be insignificant. It follows that the favorable influence of the phosphate feeding is

reduced to negligible proportions in the case of cows which have been superabundantly fed in their immediately preceding lactation period.

EFFECTS OF PHOSPHATE FEEDING ON BODY WEIGHT.

Both the animals on the experimental feeding and those used as controls were weighed from time to time. The results are given in Tables 4, 5, 6, and 7. These figures summarize all the pertinent results that we have. Heifers 67 and 214 were fed on the control rations in the late winter of 1917–18 and changed over to the experimental rations a few weeks before they calved. They, therefore, figure as controls in Table 4 and as experiment animals in Table 2. They were on the experimental feeding for such short periods that the weights obtained from them during those periods can not be used in the present discussion.

TABLE 4.—*Heifers on control rations; all four pregnant.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
67	20	1.75	Grain C	3	Alfalfa hay	4	Corn silage	30
71	60	0.65	do	3	do	4	do	30
81	180	1.04	Grain E	3	do	3	do	30
214	59	0.90	Grain C	3	do	4	do	25

TABLE 5.—*Heifers fed alternate rations with phosphate; No. 70 pregnant, No. 74 farrow.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Average daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
70	70	1.24	Grain CP_1	3	Alfalfa hay	4	Corn silage	30
74	80	2.20	do	3	do	4	do	30

TABLE 6.—*Cows fed control rations during dry periods before calving.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
17	50	1.38	Grain C	4	Alfalfa hay	4	Corn silage	30
50	59	1.76	do	5	do	4	do	30
51	47	1.28	do	3	do	4	do	30
64	60	1.32	do	6	do	5	do	30

TABLE 7.—*Cows fed alternated rations with phosphate during dry periods before calving.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Average daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
17	52	0.93	Grain CP	4¼	Alfalfa hay	4	Corn silage	30
21	80	1.57	Grain CP_1	6	do	5	do	30
50	30	2.50	do	5	do	4	do	30
71	30	1.87	Grain CP	3	do	4	do	30
81	31	1.03	do	3	do	3	do	30

It seems worth while to give in more detail the histories of two animals of which the weight changes on the experimental feeding were followed for comparatively long periods.

Heifer 74 was born October 15, 1916. From October 19, 1918, to January 15, 1919, she was fed alternated rations with phosphate, receiving as a daily average 3 pounds of grain mixture CP_1, 4 pounds alfalfa hay, and 30 pounds corn silage. She was farrow during this period. Her weights were as follows: October 24, 1918, 754 pounds; November 23, 1918, 804 pounds; December 23, 1918, 890 pounds; January 12, 1919, 930 pounds.

Cow 21 was born in 1907. From August 28 to November 30, 1918, she was fed alternated rations with phosphate, receiving as a daily average 6 pounds of grain mixture CP_1, 5 pounds alfalfa hay, and 30 pounds corn silage. She had calved November 7, 1917, and became dry September 6, 1918. She calved again November 30, 1918. During the period of phosphate feeding her weights were as follows: September 2, 1,027 pounds; October 2, 1,107 pounds; November 1, 1,143 pounds; November 21, 1,153 pounds.

Her best previous month's record for milk yield on the Beltsville farm was made in October, 1914, and amounted to 1,041 pounds. After this her milk yield gradually fell off; the best month's production after the 1917 calving was 469 pounds. She was in very good condition when she calved in 1918; in December, 1918, she produced 1,276 pounds of milk, and in January, 1919, 1,315 pounds.

These two cases show clearly that sodium phosphate may be fed to cows for long periods in large amounts without producing any deleterious effects on the digestive and assimilative processes.

QUANTITATIVE RESULTS.

In Table 8 and figure 3 an attempt is made to estimate how much the alternated feeding with phosphate increased the milk yield in the cows of the general herd under the conditions of our experiments. The column headed "Expected yield after alternated rations with

phosphate" gives the milk yields to be expected after the experimental feeding, using the yields after the control feeding as a basis and taking into account the facts that some of the animals aborted, and that the last four were heifers with their first calves in the control period and with their second or later calves in the experimental period. The figures represent the milk yield in 30 days beginning soon after calving.

TABLE 8.—*Expected and actual 30-day milk yields of cows from the general herd after alternated phosphate feeding: actual yields after control feeding.*

No. of animal.	Actual milk yield after control rations.	Expected milk yield after alternated rations with phosphate.	Actual milk yield after alternated rations with phosphate.
	Pounds.	*Pounds.*	*Pounds.*
17	847	847	858
49	831	565	953
50	995	995	972
54	669	599	1,027
63	422	495	1,018
71	632	739	1,121
81	685	753	936
Total	5,081	4,993	6,885

The actual yields after the alternated feeding with phosphate average 37.9 per cent more than the expected.

GRAIN MIXTURES USED IN EXPERIMENTS.[9]

GRAIN MIXTURE A.

Corn meal	45 pounds.
Wheat bran	36 pounds.
Cottonseed meal	18 pounds.
NaCl	1 pound.

GRAIN MIXTURE C.

Corn-and-cob meal	45 pounds.
Wheat bran	36 pounds.
Cottonseed meal	18 pounds.
NaCl	1 pound.

GRAIN MIXTURE CP_1.

Grain C	100 pounds.
Na_2HPO_4. $12H_2O$	10 pounds.

GRAIN MIXTURE D.

Hominy grits	45 pounds.
Ground oats	36 pounds.
Cottonseed meal	18 pounds.
NaCl	1 pound.

GRAIN MIXTURE B.

Corn meal	40 pounds.
Wheat bran	40 pounds.
Cottonseed meal	20 pounds.
NaCl	1 pound.

GRAIN MIXTURE CP.

Grain C	100 pounds.
Na_2HPO_4. $12H_2O$	11 pounds.

GRAIN MIXTURE CP_2.

Grain C	100 pounds.
Na_2HPO_4. $12H_2O$	6 pounds.

GRAIN MIXTURE DP.

Grain D	100 pounds.
Na_2HPO_4. $12H_2O$	19 pounds.

[9] The cottonseed and linseed meal used in these mixtures were meals from which the fat had been extracted by the old process—heat and pressure without solvents.

GRAIN MIXTURE E.

Corn-and-cob meal	55 pounds.
Wheat bran	30 pounds.
Linseed meal	15 pounds.
NaCl	1 pound.

GRAIN MIXTURE F.

Ground oats	28 pounds.
Linseed meal	20 pounds.
Cottonseed meal	10 pounds.
Gluten feed	14 pounds.
Hominy feed	14 pounds.
Wheat bran	14 pounds.
NaCl	1 pound.

ACCOUNT OF UNSUCCESSFUL AND INCOMPLETE EXPERIMENTS.

Many experiments on the effects of phosphate feeding were begun and then had to be abandoned because the animals aborted or failed to calve, or for other reasons. In other cases phosphate was fed to certain animals, but under rather different circumstances from those in the experiments which have been reported. We wish to mention briefly these unsuccessful and incomplete experiments partly because the results sometimes furnished interesting hints, partly in order to avoid any suspicion that the results reported for the successful experiments might be cases unconsciously selected in which the milk yield happened to be large after the phosphate feeding.

Several animals were started on the control rations, and subsequently either aborted or turned out to be sterile. It is not necessary to say anything about these further than that, in the cases where they aborted, the milk yields were such as would be expected from a consideration of their histories in comparison with those of the rest of the general herd.

Cow 63, whose 1918 and 1919 lactation periods have already been described in detail, was started again on the basal rations in 1920. She carried her calf to term, but acquired an acute general infection after she had been milking about two weeks, which rapidly reduced her milk yield to a very low point, and finally made it necessary to have her slaughtered. She began this lactation period, however, with a milk yield which promised to be as good as or better than that of 1919 after the phosphate period. It is to be remembered that her dry period in 1919 on the phosphate feeding was 103 days; and her dry period in 1920 was also about 100 days. We are inclined to think that these long dry periods made it possible for her to store up a good quantity of calcium and phosphorus, and it would not be surprising if the effect of the long dry period with phosphate feeding in 1919 lasted into 1920.

Several cows started on the phosphate feeding turned out to be sterile; and one aborted in addition to cows 49 and 54, whose histories have already been reported in detail. The abortion in question occurred at a period when it was the custom to remove aborting cows from the farm immediately, and before we realized that cows which

aborted after a period on the phosphate feeding might give more milk than they ever had before. We have no knowledge of the amount of her milk yield after the abortion.

Besides the cases so far reported, there are only seven animals which received any sodium phosphate at all. One of these received small daily doses (6.9 grams phosphorus as sodium phosphate) from the time she was born to when she dropped her first calf. She aborted with this calf, and gave a rather small quantity of milk subsequently. On account of the abortion and of the fact that the doses of phosphate were small, we do not think that this experiment throws any light at all on the question of the effects of phosphate feeding on the subsequent milk yield.

The six other animals received basal rations alone and then the same rations with phosphate added for short alternated periods, the main purpose of the experiments being to determine the effects of feeding phosphate on the concentration of phosphorus in the blood. Three of these happened to abort after periods of a week or more on rations without phosphate. They gave about the quantities of milk which would have been expected on the supposition that they had never had phosphate.

The other three dropped their calves while on the phosphate feeding. Two of them aborted after 7 and 10 days of phosphate feeding respectively. Both gave more milk than they ever had before, and decidedly more than would have been expected on the supposition that they had never had phosphate. The third was a heifer carrying her first calf. She calved normally at term after 26 days of phosphate feeding and gave much more milk than the general average for the herd with their first calves. These last three results suggest that even a short period of phosphate feeding may have a markedly favorable effect on milk yield if it occurs during the few days immediately before calving, during which the udder is rapidly enlarging in preparation for the coming lactation period.

LITERATURE CITED.

(1) Bertram, J. 1878. Ueber die Ausscheidung der Phosphorsäure bei den Pflanzenfressern. *In* Ztschr. Biol., v. 14, pt. 3, p. 335–382.

(2) Eckles, C. H. and Palmer, L. S. 1916. The influence of the plane of nutrition of the cow upon the composition and properties of milk and butterfat. Mo. Agr. Exp. Sta. Research bul. 25.

(3) Eckles, C. H. 1916. The nutrients required to develop the bovine fetus. Mo. Agr. Exp. Sta. Research bul. 26.

(4) Forbes, E. B., with collaborators. 1914. The metabolism of organic and inorganic compounds of phosphorus. Ohio Agr. Exp. Sta., Tech. ser. bul. 6, p. 66.

(5) Forbes, E. B., with collaborators. 1916–1918. The mineral metabolism of the milch cow. Ohio Agr. Exp. Sta. Buls. 295, 308, and 330.

(6) GOUIN, A., and ANDOUARD, P. 1902–1903. Nouvelles recherches sur la nutrition des jeunes bovidés. *In* Bul. Sta. Agron. Loire-Inf., p. 66–100.

(7) HAMMARSTEN, O. 1915. A text-book of physiological chemistry. Translated by J. A. Mandel. 7th ed. p. 762.

(8) HART, E. B., MCCOLLUM, E. V., and HUMPHREY, G. C. 1909. The rôle of the ash constituents of wheat bran in the metabolism of herbivora. *In* Amer. Jour. Physiol., v. 24, no. 1, p. 86–103.

(9) HENRY, W. A., and MORRISON, F. B. 1915. Feeds and feeding. 15th ed. p. 133.

(10) Same. p. 668.

(11) Same. p. 113.

(12) MEIGS, E. B., BLATHERWICK, N. R., and CARY, C. A. 1919. Contributions to the physiology of phosphorus and calcium metabolism as related to milk secretion. *In* Jour. Biol. Chem., v. 37, no. 1, p. 1–75.

(13) MEIGS, E. B. BLATHERWICK, N. R., and CARY, C. A., with the collaboration of Woodward, T. E. 1919. Further contributions to the physiology of phosphorus and calcium metabolism of dairy cows. *In* Jour. Biol. Chem., v. 40, no. 2, p. 469–500.

(14) PEARL, R., and PATTERSON, S. W. 1917. The change of milk flow with age, as determined from the seven day records of Jersey cows. Me. Agr. Exp. Sta. Bul. 262.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 946

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C. PROFESSIONAL PAPER February 21, 1921

COMPARATIVE SPINNING TESTS OF MEADE AND SEA ISLAND COTTONS.

By Wm. R. Meadows, *Cotton Technologist*, and W. G. Blair, *Assistant in Cotton Testing.*

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The ravages of the boll weevil have reduced the annual production of Sea Island cotton in the United States from 92,619 bales in 1917 to 6,916 in 1919, and the prospect for the crop of 1920 indicates an even lower figure. From present indications it is feared that the entire industry may be destroyed within the next few years. However, the Bureau of Plant Industry of the United States Department of Agriculture has developed a new variety of cotton which promises to replace the rapidly diminishing Sea Island crop. This new variety is known as "Meade."

The introduction of new varieties of cotton is usually attended with many difficulties because growers and manufacturers are reluctant to change from a well-known variety which has given satisfactory results for many years to another variety that is in the experimental stage of development. Such was the condition which prevailed at the time that the Meade cotton was first introduced in the Sea Island districts. The principal reason for experimenting with this new variety was to prepare for the damage that was expected would result to Sea Island cotton if the boll weevil should reach this region. It is thought that Meade has now been established on a commercial basis and that its future production is assured.

The Meade cotton was developed during 1912 and subsequent years from what was known locally as "Blackseed" or "Black Rattler"

Note.—This bulletin is of interest to the growers, cotton merchants, dealers, and manufacturers of Meade and Sea Island cottons.

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cotton grown near Clarksville, Tex. Its chief cultural characteristics as compared with the Sea Island cotton are its earlier maturing bolls increased production of lint and seed, and its larger bolls and consequent greater ease of picking.

The Meade cotton is a long-staple upland variety, producing under favorable conditions a fiber $1\frac{5}{8}$ inches long, of fine texture like the Sea Island. Because its seeds are nearly smooth it can be handled to advantage on common roller gins. There is little tendency to "butterfly"; that is, for the fibers to grow shorter at the base of the seed, which was one of the undesirable traits of the older long-staple upland varieties, such as Floradora, Sunflower, and Allen. So closely does the Meade fiber resemble Sea Island that the two can not be distinguished except by experts. It is said that Meade has been sold on the regular Sea Island market at Savannah at a premium over the mainland Sea Island.

PURPOSE OF THE SPINNING TESTS.[1]

The United States Department of Agriculture, through the cotton-testing specialists of the Bureau of Markets, has conducted spinning tests on representative bales of Meade and Sea Island cotton grown during the seasons of 1916–17, 1918–19, and 1919–20 in order to determine the practical spinning value of the Meade cotton in comparison with that of Sea Island.

GRADE AND STAPLE OF COTTON.

The grade of the cotton for the tests of 1916–17 and of 1918–19 was practically equal. That of the season of 1919–20 was represented by a mixture of Meade cotton grading No. $2\frac{1}{2}$, grown on sandy soil; by another mixture of Meade cotton grading No. 3, grown on clay soil; and by a mixture of Sea Island cotton grading No. $1\frac{1}{2}$. The length of staple of the cotton tested was $1\frac{5}{8}$ inches for all three seasons, excepting the Meade produced on clay soil, which was $1\frac{7}{16}$ inches in length of staple. The United States Official Cotton Standards for Sea Island cotton were used as a basis of comparison for both growths on which the 1919–20 tests were made, but the earlier tests were made before the official standards for Sea Island had been established; hence, it can only be stated that the grade of cottons used the first two years was equal as between Meade and Sea Island and approximately equal to the grades used in the last test.

[1] The spinning tests of the Meade and Sea Island cottons herein described were conducted independently during three different years. The test on the crop of 1916–17 was made in 1917 at the North Carolina State College of Agriculture and Engineering, West Raleigh, N. C., by William S. Dean, formerly assistant in cotton testing; the test on the crop of 1918–19 was made in 1919 at the New Bedford Textile School, New Bedford, Mass., by C. E. Killingsworth, formerly assistant in cotton testing; and the tests of the crop of 1919–20 were made in 1920 at the North Carolina State College of Agriculture and Engineering, West Raleigh, N. C., by William G. Blair, assistant in cotton testing.

MECHANICAL CONDITIONS.

All of the test lots were run under the same mechanical conditions except for minor changes in the draft to secure the required weight of sliver. These changes were necessary because the Meade was slightly more wasty than the Sea Island.

PERCENTAGES OF WASTE.

Accurate records were kept of the amount of cotton fed to and delivered by each machine and of the waste discarded at each process. The invisible loss depends upon the grade of the cotton and the atmospheric conditions under which it is being manufactured. To offset the effect of the latter an attempt was made to maintain the relative humidity at 65 per cent, but because of the absence of humidifiers in the picker room it was not always possible to keep a constant humidity in that room, which caused slight variations in the invisible loss.

Table 1 gives the percentages of visible waste obtained at the pickers, cards, and combers; the invisible waste; and the combined visible and invisible waste from both the Meade and Sea Island cottons tested.

TABLE 1.—*Percentages of waste obtained from Meade and Sea Island cotton during the seasons shown.*

	1916–17		1918–19		1919–20		
	Meade cotton.	Sea Island cotton.	Meade cotton.	Sea Island cotton.	Meade cotton, sandy soil.	Meade cotton, clay soil.	Sea Island cotton.
Visible waste:							
Pickers [1]	1.80	1.04	1.63	1.63	2.34	3.14	1.05
Cards [1]	7.66	7.04	5.70	5.32	6.49	10.01	5.03
Combers [1]	22.45	23.26	19.39	15.03	18.85	16.12	15.20
Total visible [2]	29.48	29.34	24.82	20.55	25.51	26.19	19.79
Invisible waste [2]	.74	.27	2.12	.74	2.54	3.97	3.63
Total visible and invisible waste from pickers, cards, and combers [2]	30.22	29.61	26.94	21.29	28.05	30.16	23.42

[1] Based on the net weight fed to the respective machines.
[2] Based on the net weight fed to the opener picker.

These waste percentages show that the Meade and Sea Island cotton were practically equal in wastiness for the season of 1916–17, the percentages of visible waste being 29.48 and 29.34, respectively. The tests made on the cotton grown in the season of 1918–19 show that there was 4.27 per cent more visible waste in the Meade than in the Sea Island cotton. This difference was almost entirely due to the waste made on the comber. The tests made on the crop of 1919–20 showed a difference of 5.72 per cent more visible waste for the sandy soil and 6.40 per cent for the clay soil Meade than for the Sea Island.

The greater part of this difference in waste occurred at the pickers and cards, and may be partly accounted for by the lower grade of the Meade selected for the test.

On averaging the results of the tests for the three seasons, it was found that on the pickers, the Meade cotton was 0.82 per cent more wasty than the Sea Island; on the cards, 1.40 per cent; on the combers, 1.94 per cent; and for all three processes, 3.50 per cent. The difference on the comber could be eliminated by slight adjustments of this machine, so that the difference in the wastiness of the two cottons might be reduced to an almost negligible amount.

BREAKING STRENGTH OF YARN.

Both growths of cotton were spun into 23's, 40's, 60's, 80's, and 100's yarn. Each number of yarn was produced with three different twists, namely those indicated by the twist multipliers 3.25, 3.50, and 3.80. That is, these figures multiplied by the square root of the number of yarn being spun give the turns of twist per inch in the yarns. The results of the twist tests were not conclusive in that they show some cases in which the strength of the yarn increased on changing the twist multiplier from 3.5 to 3.8, and other cases in which the strength decreased with the greater twist. The same facts were evident when the twist multiplier was changed from 3.5 to 3.25.

A comparison of the breaking strengths of the Meade and Sea Island cottons is shown in Table 2, in which the breaking strength in pounds per skein of 120 yards for the various numbers of yarn having a twist equal to 3.5 times the square root of the number of yarn is given.

TABLE 2.—*Breaking strength, in pounds, per skein of 120 yards of various sizes of yarns spun from Meade and Sea Island cotton grown in different seasons.*

(3.50 twist multiplier used.)

Season.	Size of yarn.	Meade cotton.		Sea Island cotton.
1916–17	23's	129.7		144.7
	100's	15.2		17.4
1918–19	23's	109.2		128.7
	40's	60.1		69.8
	60's	35.4		39.4
	80's	24.1		25.9
	100's	16.3		17.6
		Sandy soil.	*Clay soil.*	
1919–20	23's	103.8	107.69	122.6
	40's	54.6	53.5	58.5
	60's	33.7	30.7	34.8
	80's	22.6	19.6	22.3
	100's	15.5	12.8	15.6

During the seasons of 1916–17 and 1918–19, when the Meade and Sea Island cottons were grown under normal conditions, the breaking strength of the yarns spun from Meade cotton was weaker than

that of the Sea Island, regardless of the number of yarn spun. During the season of 1919–20, excessive rains in the Sea Island district weakened the strength of the fiber of both cottons before they were picked. The Sea Island cotton was apparently affected more than the Meade, as shown by the breaking strengths of the finer numbers. On the coarser numbers, the Sea Island had the greater strength, whereas on the finer numbers, the two varieties were practically equal in strength.

The Meade cotton grown on clay soil gave a stronger break on 23's yarn than that grown on the sandy soil, but on the finer numbers, the greater breaking strength was obtained from the Meade grown on sandy soil.

SUMMARY.

Meade cotton has been developed as a possible substitute to replace the rapidly diminishing supply of Sea Island cotton. Its length of staple varies from $1\frac{7}{16}$ to $1\frac{3}{4}$ inches, the greater portion being $1\frac{5}{8}$ inches. It matures two to three weeks earlier, gives a greater production of both lint and seed, and is more easily picked than Sea Island.

The grade and staple of the Meade and Sea Island cottons tested were practically equal for the seasons of 1916–17 and 1918–19, but were unavoidably different for the season of 1919–20.

The cotton was run under as nearly identical conditions as possible.

Averaging the visible waste for the three seasons, it was found that the Meade cotton was 3.50 per cent more wasty than the Sea Island.

Comparing the breaking strength of the Meade and Sea Island yarns for the three seasons, a difference of 17.2 pounds was found in favor of the Sea Island for the 23's yarn and 1.68 pounds for the 100's yarn. Under the adverse weather conditions during the growing season of 1919–20, the breaking strength of the sandy soil Meade was equal to that of the Sea Island for the finer numbers of yarn.

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JOHN R. MOHLER, Chief

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WESTERN SNEEZEWEED (HELENIUM HOOPESII) AS A POISONOUS PLANT.

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INTRODUCTION.

HISTORICAL SUMMARY.

In 1903, V. K. Chesnut, who was at that time in charge of poisonous-plant investigations in the Department of Agriculture, while visiting Sevier County, Utah, was told that a disease of sheep was prevalent in that part of the State. The disease was characterized by vomiting and wasting away, the sheep dying after a time varying from a week or two to a month. Nothing further was heard of this disease by the department until January, 1914, when the senior author, who was making an address to the stockmen of Salina, Utah, was told that the sheep on the summer ranges in the Wasatch Mountains

suffered from a disease commonly known as "spewing sickness." The symptoms, as described, seemed to correspond fairly well with those caused by *Zygadenus* (death camas), and the men were told that this plant was the probable cause. A picture of the plant was shown, and some of them recognized it as growing on the ranges where the trouble occurred.

A botanical examination of the ranges in question was made by W. W. Eggleston in the following summer, and two visits were made by Dr. Hadleigh Marsh to see the sick animals. On the first visit, from July 25 to August 7, 1914, a number of spewing cases were seen and some autopsies made. The "sneezeweed," *Helenium hoopesii*, was seen where some of the sheep were grazing, and one of the herders expressed his belief that this plant was the cause of the trouble. It was found, however, that quite generally *Zygadenus* grew near where cases of poisoning occurred, and it was concluded that this plant was the probable cause of the trouble, although it was noted that the cases were not typical of *Zygadenus* poisoning, and that *Zygadenus* was not found in some of the localities. It was also found that many cases occurred in September, which was rather late for *Zygadenus*. The second visit was made by Dr. Hadleigh Marsh, from September 12 to 21. This was just after the sheep had left the summer range. The localities where sheep had been reported poisoned were examined carefully. Dried leaves and seed of *Zygadenus* were found in many places. It was thought that the *Zygadenus* was abundant enough to account for some of the losses, but not for all. The fact, too, that most of the herders believed in the sneezeweed as the poisonous agent was not to be ignored, and it was felt that definite experimental work should be undertaken which would verify or eliminate the sneezeweed theory.

This experimental work was commenced when the Salina Experiment Station was established on the Fishlake National Forest in 1915, and has been continued for five years. The installation of a station on a range where the spewing sickness was common, with the opportunity of observing the field cases, together with feeding experiments with the fresh plant, soon established proof that the spewing sickness was not caused by *Zygadenus*, but was the result of eating sneezeweed (*Helenium hoopesii*). A preliminary publication, Circular A–9, United States Department of Agriculture, was issued concerning this work in 1916. The effects of the plant were of such a character, however, as to make the detailed experimental work very slow and tedious, and in the course of the work many perplexing questions arose, so that it was only after several seasons' work that it was possible to make a fairly complete report on the subject.

The following references to the poisonous properties of *Helenium hoopesii* have been found in the literature:

Pammel (1910, p. 140) says that it is "said to be poisonous to sheep."

In 1911, page 781, he says:

> It is said to be poisonous like other species of the genus. Sheep carefully avoid it, feeding on the grass and other herbaceous plants, leaving the plant standing.

Barnes (1913) states that "sneezeweed (*Helenium autumnale, Helenium montanum*)" grows all over the West and is poisonous to sheep. He also says that water from tanks in the sneezeweed region may poison sheep and has poisoned men. With very little doubt the sneezeweed he speaks about is *Helenium hoopesii*.

Glover and Robbins (1915, pp. 66–67) give a brief description of "*Dugaldia hoopesii*" and state that "in the mountainous districts of Colorado bitter milk and meat are not uncommon, and it can no doubt be safely attributed in many instances to the eating of this plant. Severe poisoning may result from eating large quantities of the plant."

Hall and Yates (1915, p. 246) include *Helenium hoopesii* in a list of plants "either definitely known to be poisonous to stock or are under suspicion, but which seldom, if ever, cause serious trouble in California."

Pammel (1917, p. 462) says:

> The Rocky Mountain *D. hoopesii* is a much larger plant than the eastern species. This is very common in Utah and western Colorado. I saw a great deal of this in the Uintah Mountains. Sheep were abundant on the range where I noted this plant. I found that, though sheep will eat all kinds of herbage, they carefully avoid this species. I feel sure that when forage is scarce they sometimes eat this weed and may sometimes die. The summer I was on this range hundreds of sheep died from various causes, some, perhaps, from this sneezeweed.

Marsh (1918, pp. 19 and 20) makes a summarized statement in regard to the plant.

Beath (1919, p. 45) says:

> Recently western sneezeweed is reported to have occasioned losses among sheep in certain States, especially Utah. The poison is slow in action and said to be cumulative. Its specific nature has not as yet been announced.

DESCRIPTION OF THE PLANT.[1]

Helenium (*Dugaldia*) *hoopesii* (fig. 1) belongs to the composite family and is a strong perennial, growing to a height of 1 to 3 feet with one or several stems. It often develops a large crown and spreads vegetatively by this crown. (Fig. 3.)

The plant, when young, is often hairy or woolly, particularly the stems, but later becomes glabrous. The stem is leafy; the thick

[1] The description of the plant was prepared by W. W. Eggleston, Bureau of Plant Industry, U. S. Department of Agriculture.

entire leaves of a deep green color are dotted, have several parallel veins, are oblong, lanceolate, sessile, or in the root-leaves spatulate with a long tapering base. There may be one or several flower heads. The heads are 2 to 3 inches broad, with oblong-lanceolate scales. The ray flowers are of an orange color, numerous and fertile, about an

FIG. 1.—*Helenium hoopesii.* Mature plant in blossom.

inch long; the disk flowers are brownish orange. The seeds are numerous and hairy.

The plant occurs at elevations from 5,200 feet to 12,500 feet, but its usual limits are from 7,000 feet to 10,500. It is found in the yellow-pine belt, grows abundantly in the aspen and spruce belts,

and somestimes reaches the Arctic alpine zone. Its best habitat is on sunny slopes of the aspen-spruce belt in moist well-drained soil. It thrives in the higher mountain parks of Colorado and Utah and in the upper Kern River watershed in the southern Sierra Nevadas of California. *Helenium hoopesii* is also found in the Wind River and Teton Mountains, Wyo.; the Caribou Mountains, Idaho; in the Stein Mountains, Oreg.; the Ruby Mountains, Nev.; and in the Warner Mountains, Calif. In the Sierra Nevadas it has been found north from the Kern River to Clarks Fork, north of Sonora pass on both sides of the range, and also in Washoe County, Nev. In the higher mountains of Arizona and New Mexico it is well distributed. In the Black Mountains and the Mogollon Mountains of New Mexico it is abundant along the streams in the higher mountain canyons. In the Sacramento Mountains, N. Mex., it occurs in the bottoms of many of the

FIG. 2.—Distribution of *Helenium hoopesii* in the United States.

higher canyons that are destitute of streams. The White and the Mogollon Mountains of New Mexico and the San Francisco Peaks of Arizona have high mountain parks similar to those of the Rocky Mountains of Colorado and the Wasatch, and in these parks sneezeweed is abundant.

In the Wasatch Mountains the blossoming period is from the middle of June to the middle or last of August. In many overgrazed areas it has become the predominant plant. Figure 4 shows how thickly it grows in some localities.

From the color of the flowers it is sometimes called "yellowweed," and some stockmen called it "sunflower," but in Utah it is most commonly known as "sneezeweed." The Navajos have a name meaning owl's claws. Figure 2 shows the distribution of the plant in the United States.

EXPERIMENTAL WORK.

The feeding experiments were carried on at the Salina Experiment Station, in Utah, and were continued through the summer months from 1915 to 1919.

Facilities for chemical work were provided at the Salina station so that such work as was dependent on field conditions was conducted

FIG. 3.—*Helenium hoopesii.* Young plants showing root system and method of vegetative reproduction.

there, but the more detailed work was carried on in Washington, where laboratory facilities were more complete.

The plants used were all collected in the immediate neighborhood of the Salina Experiment Station, in the Fishlake National Forest in Utah. The weights of the plants are all given in the equivalent of the green plant.

The following table gives a summarized statement of the work with sheep and cattle and will give an idea of the extent of the experimental work on which this paper is based.

TABLE 1.—*Summary of 5-year feeding experiments with sneezeweed (Helenium hoopesii) at Salina Experiment Station, Utah, 1915 to 1919.*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Quantity of plant fed.			Length of feeding period.	Severity of sickness.	Remedy.
Designation.	Weight during experiment.				Total weight.	Per hundredweight of animal.	Daily average per hundredweight of animal.			
	Pounds.	1915.			*Pounds.*	*Pounds.*	*Pounds.*	*Days.*		
Sheep 316	68.5 to 77.5	June 23 to 26	Fed in hay	Leaves, stems, and young flowers.	1.5	2.19	2.19	1	Not sick	None.
Sheep 319	77 to 60.5	June 25 to July 15	Fed	do	63.5	82.468	3.927	21	Died	Do.
Sheep 328	87 to 65	July 3 to 22	Fed. Flowers often left uneaten.	Leaves, stems, and flowers.	65	74.713	3.932	19	Sick	Do.
Sheep 329	87 to 76.5	July 7 to 23	Fed	do	29.25	32.865	1.933	17	Not sick	
Sheep 338	79	July 15	2 forced feedings	Flowers	2.204	2.790	2.790	1	Died	Do.
Sheep 325	94.5 to 89.5	July 15 to 18	Fed	Leaves	3	3.175	.794	4	Not sick	
Sheep 335	86	July 17 and 18	1 forced feeding	Flowers	.859	.999	.499	2	Died from choking	
Sheep 343	86 to 75.25	July 17 to 22	Fed	do	7	8.140	1.357	6	Not sick	
Sheep 346	96.5 to 71	July 18 to Sept. 14	do	Leaves, stems, and flowers.	77.5	80.311	1.361	59	Sick	Do.
Sheep 348	83.5	July 19 to 29	11 forced feedings (1 per day).	Flowers	9.191	11.007	1.001	11	Died	Do.
Sheep 344	101.25 to 93.75	July 20 to 22	Fed	Leaves, stems, and flowers.	2.5	2.469	.823	3	Not sick	
Sheep 355	85.5	July 23 to 25	4 forced feedings	Radical leaves	3.421	4.001	1.334	3	Died	Do.
Sheep 357	125.5 to 101.5	July 24 to Aug. 1	Fed	Flowers	20	15.936	1.77	9	Not sick	
Sheep 341	118.5 to 104.5	July 24 to Aug. 7	do	Radical leaves	25.5	21.519	1.434	15	do	
Sheep 333	107.5 to 81	July 29 to Aug. 21	do	Leaves, stems, and flowers.	30.5	26.372	1.182	24	Weakness	Do.
Sheep 358	94	Aug. 2 to 4	5 forced feedings	Radical leaves	3.891	4.139	1.380	3	Sick	Do.
Sheep 354	95.5	Aug. 2 to 6	10 forced feedings	Flowers	7.892	8.264	1.653	5	do	Oil.
Sheep 320	93 to 88	Aug. 7	2 forced feedings	Radical leaves	2.595	2.790	2.790	1	Not sick	
Sheep 339	105.5 to 81	Aug. 8 to 27	Fed	do	28.5	27.014	1.351	20	Weakness and trembling.	None.
Sheep 314	95	Aug. 9	2 forced feedings	do	3.141	3.306	3.306	1	Died	
Sheep 326	97 to 80	Aug. 18 to Sept. 14	Fed	Leaves, stems, and flowers.	42	43.299	1.546	28	Not sick	
Sheep 330	102.5 to 88	Aug. 23 to 31	do	Radical leaves	8	7.805	.967	9	do	
Sheep 323	138 to 112.5	Aug. 23 to Sept. 19	do	do	47	34.058	1.261	27	Symptoms	Do.
Sheep 315	92 to 83	Aug. 24	2 forced feedings	do	2.434	2.646	2.646	1	Sick	Do.
Sheep 318	101 to 89	Aug. 27	do	do	2.672	2.646	2.646	1	Not sick	
Sheep 332	82.5	Aug. 31	do	do	2.051	2.486	2.486	1	Sick	Do.
Sheep 331	86.5	Sept. 1	1 forced feeding	Stem leaves	2.288	2.645	2.645	1	Died	Do.
Sheep 340	84 to 72.5	Sept. 3	3 forced feedings	do	2.222	2.645	2.645	1	Sick	Do.

TABLE 1.—*Summary of 5-year feeding experiments with sneezeweed (Helenium hoopesii) at Salina Experiment Station, Utah, 1915 to 1919*—Contd.

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Quantity of plant fed.			Length of feeding period.	Severity of sickness.	Remedy.
Designation.	Weight during experiment.				Total weight.	Per hundredweight of animal.	Daily average per hundredweight of animal.			
	Pounds.	1915.			*Pounds.*	*Pounds.*	*Pounds.*	*Days.*		
Sheep 341	121.5 to 118	Sept. 3 to 25	Fed in bran	Ripe fruits	8.629	7.102	0.309	23	Not sick	
Sheep 343	96.5 to 85.5	Sept. 6	2 forced feedings	Flowers	2.340	2.425	2.425	1	Symptoms	None.
Sheep 347	92.5 to 80.5	Sept. 7	do	Stem leaves	2.549	2.756	2.756	1	Not sick	
Sheep 328	93 to 89	Sept. 8	1 forced feeding	Leaves, stems, and flowers.	1.018	1.095	1.095	1	do	Do.
Sheep 352	107 to 90	Sept. 8 to 12	Fed	Radical leaves	2.75	2.570	.514	5	do	
Sheep 345	94.5 to 83.5	Sept. 10	3 forced feedings	Leaves, stems, and fruit.	2.500	2.646	2.646	1	Possible symptoms	Do.
Sheep 353	73 to 63	Sept. 10	1 forced feeding	Radical leaves	.805	1.103	1.103	1	Not sick	
Sheep 327	80	Sept. 11 to 17	12 forced feedings	do	6.349	7.936	1.134	7	Sick, died from choking.	Do.
Sheep 357	130 to 107	Sept. 13 to 25	Fed	do	19.75	15.192	1.169	13	Not sick	
Sheep 333	102 to 102	Sept. 15	3 forced feedings	Leaves, stems, and fruits.	2.623	2.572	2.572	1	Sick	Do.
Sheep 360	49.5 to 42	Sept. 17 to 25	Fed	Radical leaves	4.5	9.091	1.010	9	Not sick	
Sheep 366	93.5 to 88.5	Sept. 18	1 forced feeding	do	2.061	2.204	2.204	1	Sick	Do.
Sheep 380	60	May 30 to July 21	Fed in alfalfa hay	do	68.292	113.82	2.107	54	Died	Do.
Sheep 384	73 to 53.5	May 30 to July 23	do	do	87.834	120.319	2.149	56	Very sick	Alfalfa and service-berry leaves.
		1916.								
Sheep 394	70.5	June 3 to 23	do	do	35	49.645	2.364	21	Died	None.
Sheep 377	81.5 to 57.5	June 3 to 28	do	do	51	62.577	2.407	26	Very sick	Epsom salt, strychnin, oak leaves, and alfalfa.
Sheep 386	78.5	June 18 to Aug. 8	do	Stems, stem leaves, and flowers.	60.575	77.166	1.484	52	do	Alfalfa and bran.
Sheep 389	71 to 63	June 20 to July 22	do	Radical leaves	55.875	78.697	2.385	33	do	Alfalfa and service-berry leaves.
Sheep 378	71.5 to 65.5	June 29 to Aug. 13	do	Flower heads	64.095	89.643	1.949	46	Sick	Alfalfa and pasture.
Sheep 373	99 to 85	July 5 to Aug. 22	do	do	71.334	72.055	1.471	49	Very sick	Epsom salt and pasture.
Sheep 385	93.5 to 76	July 22 to Aug. 26	do	Stems, stem leaves, and flowers.	45.844	49.074	1.363	36	do	Epsom salt, strychnin, and pasture.
Sheep 333	102.5 to 92	July 22 to Aug. 22	do	Radical leaves	52.751	51.464	1.715	30	do	Epsom salt and pasture.
Sheep 339	120 to 111	July 24 to Aug. 25	do	do	77.833	64.861	1.965	33	do	Epsom salt, strychnin and pasture.
Sheep 357	130 to 121.5	Aug. 5 to Sept. 1	do	do	65.285	50.219	1.794	28	do	Pasture.
Sheep 401	117.5 to 113.5	Aug. 9 to Sept. 7	do	do	60.113	51.160	1.705	30	Sick	Linseed oil, glycerin, and pasture.

Sheep 393	93.5 to 83	Aug. 11	2 forced feedings	do	2.346	2.509	2.509	1	Very sick	None.
Sheep 403	111.5 to 110	Aug. 26 to Sept. 2	Fed in alfalfa hay	do	2.355	2.112	.264	8	Not sick	
Sheep 392	121.5 to 104	Sept. 6 to 23	Dried and fed in alfalfa hay.	do	44	36.214	2.012	18	Very sick	Raw linseed oil.
Sheep 395	114 to 105.5	do	do	do	32.752	28.730	1.596	18	Probable symptoms.	Pasture.
Sheep 374	115 to 105.25	Sept. 8 to 23	do	do	54.832	47.680	2.980	16	Very sick	Linseed oil and glycerin.
Sheep 375	113 to 105	do	do	do	32.168	28.467	1.779	16	Sick	Linseed oil, glycerin, and pasture.
Sheep 377	79 to 76.25	Sept. 10 to 13	Fed in alfalfa hay	do	4.583	5.801	1.450	4	Not sick	
Sheep 376	101.5 to 99.5	Sept. 21	Dried and given in 2 forced feedings.	do	3.527	3.475	3.475	1	Slight depression	None.
		1917.								
Sheep 411	65.5 to 57	June 8 to 23	Fed in alfalfa hay	Radical leaves	33.5	51.145	3.196	16	Very sick	Paraffin oil.
Sheep 412	55 to 44	June 8 to July 6	do	do	35.25	64.091	2.210	29	do	Paraffin oil and strychnin, Fowler's solution.
Sheep 423	88.5 to 77.5	June 8 to July 13	do	do	47	53.107	1.475	36	do	Linseed oil and glycerin.
Sheep 414	89.5 to 85.25	June 11 to 23	do	do	[1] 2	[1] 2.236	[1] .172	13	Not sick	
Sheep 418	77 to 75	June 8 to July 5	do	do	47.75	62.013	2.215	28	Very sick	Epsom salt.
Sheep 424	98.5	June 20	1 forced feeding	do	[1] 1.81	[1] 2.306	[1] 2.306	1	do	None.
Sheep 430	67.5 to 59.5	June 20 to July 6	Fed in alfalfa hay.	Stems and stem leaves.	[1] 47	[1] 69.630	[1] 4.096	17	Very sick	Epsom salt and strychnin.
Sheep 415	67 to 63.5	June 22	1 forced feeding	do	1.541	2.3	2.3	1	Died	None.
Sheep 413	58.75	June 24	do	do	[1] 1.400	[1] 2.383	[1] 2.383	1	do	Paraffin oil.
Sheep 432	70.25 to 62.5	June 25	do	do	[1] 1.757	[1] 2.501	[1] 2.501	1	Sick	None.
Sheep 428	76.5 to 70.5	June 26	do	Radical leaves	[1] 1.757	[1] 2.999	[1] 2.299	1	Symptoms	None.
Sheep 425	83.5 to 81.5	July 6 to 22	Fed in alfalfa hay	do	10	11.975	.704	17	Not sick	
Sheep 416	106 to 87.5	July 6 to Aug. 8	do	do	69.5	69.566	1.928	34	Very sick	Sodium cacodylate.
Sheep 409	72.5 to 58	July 7	1 forced feeding	do	[1] 1.668	[1] 2.301	[1] 2.301	1	Diarrhea	None.
Sheep 419	99.5	July 8 to Aug. 8	Fed in alfalfa hay	do	59.75	60.050	1.877	32	Died	Do.
Sheep 420	137 to 114	July 8 to Aug. 9	do	do	58.542	42.731	1.295	33	Sick	Sodium cacodylate.
Sheep 433	88.25 to 84.5	July 11 to 15	do	Flowers	[1] 2.75	3.116	.623	5	Not sick	
Sheep 454	101 to 92.5	July 18 to 22	do	do	1.75	1.733	.346	5	do	
Sheep 410	71.5 to 62.5	July 19	1 forced feeding	do	[1] 1.641	12.294	2.294	1	Symptoms	None.
Sheep 448	108.25 to 86	July 27 to Sept. 16	Fed in alfalfa hay.	Radical leaves	99.75	92.148	1.772	52	Symptoms, weakness	Do.
Sheep 446	122.5 to 104.75	July 30 to Sept. 4	do	Flowers	103	84.082	2.272	37	Very sick	Sodium cacodylate.
Sheep 437	136 to 113	Aug. 21 to Sept. 8	do	Radical leaves	55.25	38.419	2.022	19	do	Do.
Sheep 421	126.5	Aug. 27 to Sept. 18	do	do	60.625	47.925	2.083	23	do	Epsom salt and strychnin.
Sheep 439	99.5 to 86.75	Sept. 5 to 8	3 forced feedings	do	[1] 11.25	[1] 11.305	.565 / [1] 2.826	4	Sick	None.
Sheep 422	115.5	Sept. 10 to 14	5 forced feedings	do	12.448	[1] 10.776	[1] 2.156	5	Symptoms, died from choking.	Do.
Sheep 444	105.25 to 95	Sept. 13	1 forced feeding	do	2.333	2.217	2.217	1	Symptoms	Do.
Sheep 420	126 to 114	Sept. 22 to 25	5 forced feedings	do	8	6.350	.587	4	Nauseated	Do.

[1] Dry plant fed; estimated as green.

TABLE 1a.—*Summary of feeding experiments with sneezeweed (Helenium hoopesii) at Salina Experiment Station, Utah, 1918 and 1919.*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Quantity of plant fed.			Days fed.	Severity of sickness.	Remedy.
Designation.	Weight during experiment.				Total weight.	Per hundredweight of animal.	Daily average per hundredweight of animal.			
	Pounds.	1918.			*Pounds.*	*Pounds.*	*Pounds.*			
Sheep 486	98 to 82	June 13 to July 5	Fed in alfalfa hay.	Radical leaves	52	53.061	2.307	23	Sick	Tannic-acid drench.
Sheep 490	81 to 64.5	do	do	do	57	70.370	3.060	23	do	Tannic acid in salt.
Sheep 506	126 to 99.5	June 13 to July 15	do	do	99.75	79.167	2.399	33	do	Tannic-acid drench.
Sheep 467	108 to 94	June 13 to July 22	do	do	58	53.704	1.343	40	Not sick	
Sheep 481	80 to 87	June 17 to July 4	do	do	45	56.250	3.125	18	Sick	Oak leaves.
Sheep 492	113 o 103	June 17 to July 7	do	do	41	36.283	1.728	21	Not sick	Do.
Sheep 468	82 to 79	July 13	Force fed	do	1.75	2.134	2.134	1	do	
Sheep 479	93 o 83.5	July 17	do	do	2.3	2.473	2.473	1	Not sick (depressed)	
Sheep 461	80 to 75.5	July 22	do	do	2.268	2.835	2.835	1	Symptoms	None.
Sheep 471	127 to 112.5	Aug 9 to 29	Fed in alfalfa hay.	do	[1] 56	[1] 44.094	[1] 2.1	21	do	Do.
Sheep 472	104.5 to 88.5	Aug. 9 to 30	do	do	[1] 36	[1] 34.45	[1] 1.566	22	Sick	Do.
Sheep 505	95.5	Aug. 17	Force fed	do	2.375	2.484	2.484	1	Died	Do.
Sheep 469	104 to 77.5	Aug. 26 to Sept. 19.	Fed in alfalfa hay.	do	51.5	49.519	1.981	25	Sick	Do.
		1919.								
Cattle 824	366 to 324	June 2 to Aug. 3	do	Leaves, stems, buds, and flowers.	373	101.91	1.62	63	do	Do.
Cattle 827	447 to 324	Aug. 5 to Sept. 12	do	Leaves and stems.	216	48.32	1.24	39	do	Do.

[1] Dry plant fed; estimated as green.

FEEDING EXPERIMENTS WITH SHEEP.

In the experimental feeding two distinct plans were followed—corral feeding and forced feeding.

Corral feeding.—In the early experience in corral feeding the animals were given nothing but sneezeweed, which was supplied in as large a quantity as they would eat. Inasmuch as some of these feedings were continued for a considerable period, in some cases three weeks or more, the question naturally arose whether insufficient nutrition did not play a large part in the production of symptoms. This was later definitely proved to be not the case. It was found, moreover, that the animals could be induced to eat only a limited quantity of the plant, and that this quantity was fully as great when hay was supplied with it. Some of the animals were fed as long as they would eat the plant without regard to whether it produced death, while in other cases the feeding was continued only to the time when definite symptoms appeared.

Forced feeding.—In the forced feedings the balling gun was used and the material, ground up, was administered as rapidly as possible. As the animals did not, in all cases, take the material readily, it was sometimes necessary to repeat the feeding in order to give a toxic dose. As shown by the table, also, the forced feedings were sometimes extended over a number of days to determine the effect of definite repeated feedings given in this manner.

Typical Case of Sheep 413.

Sheep 413 may be taken as a type of the effect of a single forced feeding of *H. hoopesii*. This animal was a wether, weighing at the time of the experiment 54½ pounds. The temperature shortly before the experiment was 104.7° F., its pulse 114, and its respiration 60. The high pulse and respiration are accounted for because this animal had not been handled before and was somewhat excitable. On June 24, 1917, between 10.45 and 11.08 a. m., it was given, by the balling gun, 2.383 pounds of *H. hoopesii* leaves and stems. This material had been finely ground. At 2.05 p. m. the temperature was 103.8, the pulse 140, the respiration 60. June 25, 8 a. m., the temperature was 102.5, pulse 144, the respiration 36. At this time the animal appeared dejected and the femoral pulse could not be detected. At 2.30 p. m. the animal was very sick; the heart was beating irregularly and no femoral pulse could be felt. At 3 p. m. the pulse was not only rapid, being 156, but was irregular. At 4 p. m. the respirations became irregular. The animal showed no inclination to move about. This condition continued during the evening, the pulse rate remaining very high. On June 26, 6.25 a. m., the animal was extremely weak, while the rapid, irregular pulse and the irregularities of the respira-

tion continued. At 10.55 a. m. the animal appeared to be somewhat bloated, and breathing was noted as very irregular and noisy. The respiration was in groups of two or three, followed by holding of the breath after inspiration. These conditions continued unchanged during the day, the animal growing worse. On the morning of June 27 it was found dead.

In regard to the symptoms, it should be noted that the temperature continued during the sickness practically unchanged, the extremes being 100.6° to 105.3°. The high temperature, however, was noted only once and in repeated observations the temperature was only between 102° and 103.6°. The respiration varied somewhat more widely, running from 36 to 150. There was, however, no continued period of rapid respirations. The animal apparently had naturally a somewhat rapid pulse, as, on the day before the experiment, it was found to be 114. During the whole period of the illness, however, it ran high, going up as high as 156 and not falling below 121.

In the autopsy petechiæ were found on the surface of the heart and the trachea was somewhat congested, as were the lungs. In the alimentary canal the mucous membrane of the first, second, and fourth stomachs was congested. Congestion also was found in the duodenum, jejunum, and ileum, but not in the rectum.

There was a small mass of coagulated serum in the rumino-reticular groove and in the anterior groove of the rumen. It was noted that the blood vessels beneath the skin were somewhat congested.

Typical Case of Sheep 421.

This sheep can be taken as typical of those cases of prolonged feeding in which the principal symptom produced by the *H. hoopesii* was weakness, and in which vomiting was not exhibited. The sheep was a ram received at the station June 6, 1917, and at that time weighed 95 pounds. On August 6 and 7 an attempt was made to have the animal eat *Zygadenus elegans*. This feeding did not produce any effect. On August 27 a beginning was made of feeding *H. hoopesii*. At this time the sheep weighed 126.5 pounds. The general plan of feeding was to give the animal all the *H. hoopesii* it would eat, and with it was mixed more or less alfalfa hay to induce the animal to eat more readily. In preparing the material for feeding, ordinarily there was used from 3 to 5 times as much *H. hoopesii* as hay. In some instances, however, more hay was mixed with the uneaten *H. hoopesii*. Between August 27 and September 18 the animal ate 47.925 pounds of *H. hoopesii* per hundredweight of animal. The total days of feeding were 23, but symptoms appeared in 19 days after an average daily ration of 2.83 pounds of the plant.

The sheep ate quite readily and appeared to be in good condition until September 6, when it did not seem quite right. Distinct symp-

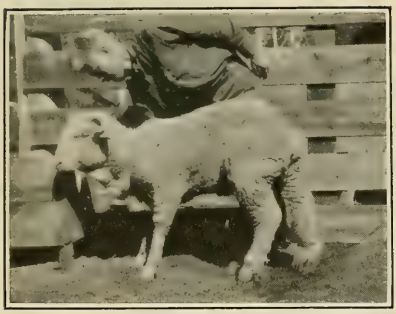

FIG. 1.—SHEEP 421, AT 10.44 A. M., SEPTEMBER 18, 1917.

FIG. 2.—SHEEP 421, AT 10.45 A. M. SEPTEMBER 19, 1917.

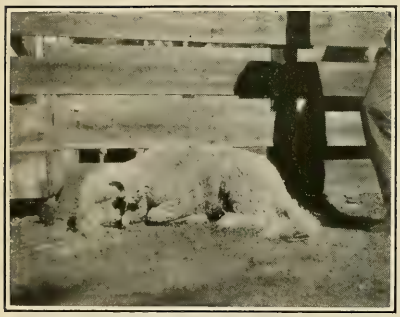

FIG. 3.—SHEEP 421, AT 10.46 A. M., SEPTEMBER 19, 1917.

FIG. 4.—SHEEP 332, IN THE ACT OF VOMITING.

FIG. 5.—SHEEP 314, IN ATTITUDE SHOWING WEAKNESS.

FIG. 6.—SHEEP 314, JUST BEFORE DEATH.

toms, however, did not appear until September 15. At that time it was still eating freely of the plant, but was gradually getting weaker, would lie down much of the time, and, when walking, dragged its hind legs. On the next day (September 16) the animal was not only lying down much of the time, but, when attempting to walk, acted as though the hind legs were stiff. On September 18 the weakness had so much increased that when standing it trembled and found great difficulty in keeping its feet. Plate I, figure 1, shows the animal at 10.44 a. m. On the afternoon of September 18 it was lying down with head stretched out, and when put on its feet was unable to stand more than a minute or two at a time. On September 19 the pulse was weak and the animal was down and did not attempt to rise. On the morning of this day it was given 3 ounces of Epsom salt and a subcutaneous injection of one-tenth of a grain of strychnin. The pulse was noted as irregular and the respirations rapid. The pictures, Plate I, figures 2 and 3, were taken at 10.45 a. m. and 10.46 a. m., and show very clearly the extreme weakness of the animal at this time. On September 20 it was given 1 ounce of Epsom salt and a subcutaneous injection of one-tenth of a grain of strychnin. The sheep was so weak that it was unable to raise the hinder part of the body from the ground. On this day the animal was regurgitating; some green mucus ran from its mouth and nostrils, but it did not vomit. On September 21 it appeared somewhat better, perhaps as the result of the action of the Epsom salt, and on this day it was given two doses of one-tenth of a grain of strychnin. The sheep was given alfalfa hay and bran and this feeding of hay was continued on the succeeding days. On September 24 the animal received 2 ounces of Epsom salt, and on September 25 appeared very much stronger. From this time there was a continual gain in the sheep's condition, and on September 28 it was turned out into the pasture. On September 30, the last day of observation, the animal weighed 103 pounds. It was evident, however, that recovery at this time was only partial, for the animal's general condition was rather bad.

Typical Case of Sheep 380.

Sheep 380 may be taken as a type of those animals subjected to prolonged feeding which, in addition to weakness, showed a pronounced tendency to vomit. The animal, a ewe weighing 60 pounds, was brought to the station May 28, 1916. The feeding was commenced on May 30 and was continued until July 21, 53 days. During that time the animal ate 113.82 pounds of *H. hoopesii*. Symptoms of poisoning, however, appeared in 25 days from the commencement of the feeding, at which time the animal had eaten 64.583 pounds.

The plan of feeding, as with Sheep 421, was to have the animal eat as much of the *H. hoopesii* as it would take. The plant was cut up and mixed with a certain amount of alfalfa hay, as the animal would not eat it without hay. The quantity of hay mixed with the *H. hoopesii* varied, being sometimes as much as one-half of the quantity of the poisonous plant. This feeding was continued from May 30, and the animal appeared in good condition with no evident symptoms of poisoning until June 23. On June 18 it was turned into the

FIG. 4.—An overgrazed range on which *Helenium hoopesii* has taken almost complete possession.

pasture with the other animals, but during the rest of the time it was confined to the corrals.

On June 23 it was noticed that while lying down the sheep regurgitated, and there was some belching of stomach gas. On June 24 some green material was noticed about the mouth, and on June 25 it was found that she had vomited. On June 27 the animal had become quite weak and was not inclined to stand. At this time she evidently, to some extent, had lost her appetite for any kind of food. The feeding, however, was continued. On June 29 the pulse was noted as somewhat irregular and the animal was lying down most of the time, although still strong enough to stand. From this time

on there were, every day, evidences of vomiting, and at times there was marked regurgitation and belching of gas and rumbling of the intestines. On July 1 it was noted that both pulse and respiration were very irregular. These symptoms continued with little change until July 7. On this day, in addition to vomiting, the animal was troubled with coughing; doubtless the coughing was caused by the irritation produced by some of the stomach contents getting into the larynx. There was no marked change after this except that the symptoms became gradually more marked. The irregularity and weakness of the pulse were more apparent and vomiting was more frequent, while the appetite gradually grew less, the animal not even caring to eat hay. On the morning of July 23 the sheep was found dead, having died some time during the night.

As there might be a question whether lack of sufficient food might not be the cause of sickness and death in cases like this, it should be stated that it was clearly proved by checking up in other cases that the weakness was not due to lack of food, but was distinctly due to the poisonous effects of the plant. In the autopsy which followed the death of the animal the only abnormal feature noted was some congestion in the fourth stomach, duodenum, jejunum, ileum, cecum, and rectum.

FEEDING EXPERIMENTS WITH CATTLE.

On the Utah ranges where the spewing sickness affects sheep there are no accounts of the poisoning of cattle by *H. hoopesii*. In following the cattle upon the range where it has been so closely grazed that very little remains except *H. hoopesii*, no evidence has been obtained of cattle grazing upon this plant. Certain reports, however, from Colorado ranges have led to the belief in the possibility of cattle being poisoned by *H. hoopesii*. Accordingly it seemed important to prove conclusively whether the plant would or would not affect cattle. Two head of cattle were treated in 1919 and both became sick as a result of the feeding, with typical symptoms resembling those produced in sheep. The following experiment with Cattle 827 may be considered as typical of the possible effect of the plant.

Case of Cattle 827.

Cattle 827 was a yearling steer received at the station on June 1, 1919, weighing at that time 340 pounds. From June 6 to 8, and on July 28, an attempt was made to have it eat aconite. The aconite produced no effect, although the animal as shown by the curve, figure 5, lost weight while in the corrals. Except for this experiment with aconite, the animal remained in the pasture until the experimental feeding of *H. hoopesii* was commenced, on August 5. The

steer had prospered up to this time and weighed on August 4, 447 pounds. The feeding continued from August 5 until September 12. The stems and leaves of the *H. hoopesii* used were ground up and mixed with chopped hay in order to induce the animal to eat. Generally speaking, about 10 pounds of the plant were prepared and mixed with 5 pounds of hay. The plan of the experiment was that the animal should be induced to eat as large a quantity of the *H. hoopesii* as possible. Both this and the other animal very much preferred hay and frequently would pick out the hay, leaving a large portion of the *H. hoopesii*. Under such circumstances more hay was mixed with the *H. hoopesii*, so that a fairly good average daily ration of hay was fed during this period.

Up to September 13 no symptoms were noted other than a certain amount of inactivity in the animal. The curve of weight, figure 5,

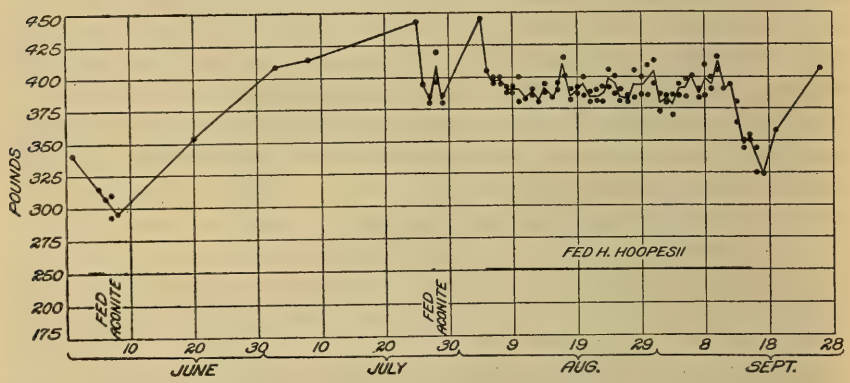

FIG. 5.—Weight curve of Cattle 827, fed aconite June 6 to 8 and July 28, and *Helenium hoopesii* August 5 to September 12, 1919.

shows that during this time the weight of the animal was maintained fairly well. On the morning of September 13 it was noticed that the animal must have been vomiting, as there were several patches of the material in the pen. The steer at this time was frothing at the mouth and regurgitating. A little later in the day he was seen in the act of vomiting. On September 14 the pulse was found to be very weak, so weak in fact that it was very difficult to count. The animal was much depressed and showed marked weakness. He was still vomiting at intervals. Figure 8 shows his attitude at 10.50 in the morning when he was regurgitating and frothing at the mouth and occasionally belching sour-smelling gas from the stomach.

These conditions continued on the succeeding days, the vomiting being more pronounced, the pulse continuing weak, and the general weakness of the animal increasing. No more *H. hoopesii* had been fed after September 12, and comparatively little hay had been eaten. On the afternoon of September 17 the animal was turned into the

FIG. 1.—SHEEP 374, SHOWING DEPRESSION AND WEAKNESS.

FIG. 2.—SHEEP 358, EXHIBITING SALIVATION.

FIG. 3.—SHEEP 361, A RANGE ANIMAL (LARGE SHEEP IN FOREGROUND), IN POSITION OF VOMITING.

FIG. 4.—SHEEP 420, NAUSEATED.

FIG. 5.—CATTLE 827, SHOWING NAUSEA.

FIG. 6.—CATTLE 827 VOMITING.

pasture; an observer followed him and succeeded in getting photographic records of the vomiting, one of which is shown in Plate II, figure 6. He was kept in the pasture the rest of the season until about the first of October. During this time as shown in the curve of weight, figure 5, he gained a little in weight, but was not in good condition. On September 26 he weighed 409 pounds. A report received from the owner of the animal December 17, 1919, indicates that after being taken from the range the animal remained in poor condition, and there is reason to assume that the injury produced by the feeding of *H. hoopesii* was permanent.

CHEMICAL EXAMINATION OF THE PLANT.

No previous analysis of *Helenium hoopesii* has been published. A nearly related plant, *Helenium autumnale*, the sneezeweed of the eastern United States, has been investigated by Koch (1874) and Reeb (1910). The latter isolated the substance of the formula C_{20} H_{25} O_5, which he called "helenic acid." The pharmacology of this was investigated by Lamson (1913), who named it "helenin"—an unfortunate choice, since that name was already established in science and commerce for a mixture of lactones obtained from *Inula helenium*. It was thought probable that the *H. hoopesii* would be found to contain helenic acid or a nearly related substance. A thorough chemical search, however, failed to reveal the presence of helenic acid or of any toxic compound which resembles it in physical and chemical characteristics.

The poisonous properties of *Helenium hoopesii* depend upon the presence of very small quantities of an exceedingly toxic glucosid to which the name "dugaldin" has been given. This occurs most abundantly in the leaves. It is found also in the stems, flowers, and seeds and in minute amounts in the root. Careful investigation of all the other constituents of the plant has shown that they are nontoxic to sheep and guinea pigs.

Dugaldin may best be prepared from the juice of the fresh radical leaves of *H. hoopesii*. The juice is expressed from the shredded leaves, which yield 40 to 60 per cent of brown, very bitter juice, the quantity depending on their age and the climatic conditions. The juice is preserved with 0.5 per cent of chloroform, allowed to stand 12 hours to settle, and filtered. The filtrate is then treated with animal charcoal which is kept suspended in the liquid by frequent stirring or shaking. After 4 to 7 days, the glucosid and coloring matters will have been adsorbed by the charcoal. The mixture is now filtered, when the filtrate appears colorless and slightly sweet instead of bitter and is nontoxic even in large doses. The animal charcoal which

remains on the filter paper is washed with water, dried at ordinary temperature, and extracted with warm alcohol, which dissolves the dugaldin with a little coloring matter and sugar. The alcoholic solution is evaporated to dryness at a low temperature; the residue is treated with absolute alcohol, and the solution is filtered off. This is boiled with a little fresh animal charcoal, filtered, cooled, and a large volume of ether is added, when the glucosid precipitates out in white flocks. The yield is less than 0.01 per cent of the green leaves taken.

As thus prepared dugaldin is a white, amorphous substance soluble in alcohol; less soluble in water, chloroform, acetone, and pyridine; sparingly soluble in acetic ether; insoluble in ether, benzene, and petroleum ether. It is soluble in aqueous solutions of the alkalies and forms a slightly soluble compound with lead. Its barium salt is insoluble in alcohol. The glucosid is readily decomposed; when treated with acids or on heating with water it hydrolyzes, yielding a sugar which reduces Fehling's solution in the cold, and a brown resin which is still being studied. Attempts to crystallize the glucosid in quantity have not been successful.

Reactions of the glucosid.—Ferric chlorid gives no coloration. Tannic acid precipitates the glucosid from its solutions. Bromin water precipitates an addition compound which is soluble with decomposition in hot water. On acetylation the glucosid is decomposed. Acid solutions of the glucosid form a cloud with Mayer's solution. Uranyl acetate produces a transient precipitate insoluble in alkalies and soluble in hydrochloric acid. Potassium permanganate is immediately reduced. Cold chromic-acid mixture gives no change, but on heating, the mixture is completely reduced, forming a green solution. A mixture of hot nitric and sulphuric acids nitrates the glucosid, forming a yellow solution. On dilution with water a yellow nitro derivative is precipitated which is soluble in alkalies.

Chemical Experiments.

The material used for the chemical examinations was collected at the experiment station, Salina, Utah. When green material was used, it was collected and ground through a meat chopper immediately before being used. The dry material used was air-dried under cover until the weight was nearly constant. It was then preserved in cloth bags.

1. *Moisture, ash, extract.*—Air-dried samples of radical leaves in No. 60 powder were used for the following determinations:

	Per cent.
Moisture	9.70
Ash	16.86

Ten grams were extracted with various solvents in succession:

	Grams.	Per cent.
Petroleum ether extracted	0.5065	5.06
Ether extracted	0.4800	4.80
Chloroform extracted	0.1611	1.61
Alcohol extracted	1.5834	15.83
Total		27.30

The ash contained a large proportion of calcium carbonate. The petroleum-ether fraction contained a phytosterol. The ether extract contained fats and a trace of tannin; the chloroform extract consisted of resins, tannin, and dugaldin; the alcohol extract contained resin, sugar, dugaldin, tannin, and coloring matter.

2. *Juice.*—Total solids, 9.80 grams per 100 ml.; specific gravity, 1.042 to 1.052 at 25°; tannin precipitates, 0.335 to 0.364 per cent.

3. *Alkaloids.*—The various samples of juice and of aqueous and alcoholic extracts of the plant, after acidification, yield precipitates with Mayer's solution. They were, therefore, investigated for the presence of an alkaloid, but no substance of this class could be isolated from any part of the plant.

4. *Hydrocyanic acid.*—Samples of green and of air-dried leaves were tested for cyanides as a routine procedure without yielding any evidence of their presence.

5. *Toxic saponins.*—Extractions of green and of air-dried leaves were made to isolate toxic saponins and several other extractions, as well as the juice from the leaves, were tested for saponins without revealing their presence. Extracts of the plant strike a green color with aqueous ferric chlorid, but this is due to the presence of a tannin which is precipitated by gelatin solution.

6. *Volatile toxins.*—Eight hundred and fifty grams of air-dried *H. hoopesii* radical leaves were placed in a still and 3 gallons of water added. The mixture was heated to boiling. The distillate had the characteristic odor of *H. hoopesii*, due to the presence of a minute quantity of essential oil. It reduced potassium permanganate; gave no color with ferric chlorid; and was neutral in reaction. The total volume of the distillate was 6 liters. This was fed to Sheep 429, in divided doses, without producing any effect.

7. *Search for helenic acid.*—(*a.*) A chloroform extract from 1 kilogram of dried radical leaves was freed from chloroform. Following Reeb's procedure, the extract was heated with successive portions of water on the steam bath and filtered. After cooling, the aqueous solution was greenish-yellow in color and had a very small amount of oily matter floating on the surface. It was evaporated to convenient bulk and extracted with several portions of chloroform. The chloroform dissolved out 4 grams of green solid, which was not bitter and was nontoxic.

(*b.*) Two hundred twenty-five grams of dried blossoms and seeds of *Helenium hoopesii* were ground to No. 20 powder and were extracted with chloroform in a Soxhlet. The chloroform was distilled off on a steam bath. The residue weighed 28.95 grams (12.86 per cent) and was brownish, fatty, and fluid. It was heated on a steam bath with successive portions of water for several hours and filtered. The filtrate was bitter; it was evaporated to dryness on the steam bath. The residue was a yellowish resin. This was extracted with benzene. The white insoluble residue was very bitter and contained dugaldin. The benzene soluble matter was not bitter and was nontoxic.

(*c.*) A second extraction with chloroform of 400 grams of dried blossoms and seeds yielded 12.62 per cent extract, in which no helenic acid could be found.

A tabular statement of pharmacological experiments will be found in Table 2 on page 23.

8. *Water-soluble constituents.*—Fifteen kilograms of air-dried basal leaves ground to about a No. 12 powder were extracted with water by percolation. This did not remove all the bitterness from the leaves. The percolate was brown and bitter. It was concentrated to a small volume. During this process a light-brown precipitate appeared, which consisted of albuminoids and calcium salts. This was collected, washed, and tested for toxicity to sheep. Sheep 409 received daily doses of 5 grams of this precipitate from September 4 to September 16, inclusive, receiving two doses on September 10, 11, 12, and 16—a total of 80 grams—without effect. Fifty grams were fed to Sheep 425 on September 10 without producing any effect. The concentrated aqueous solution was divided into two portions. One portion was boiled over a free flame for several hours, when a further quantity of the brown, nontoxic precipitate separated and the solution lost its bitterness, due to hydrolysis of the glucosid. During a period of four days Sheep 450 received 2,400 mils of this orally in five doses, but beyond some abdominal disturbance showed no effect. The other portion of the concentrated percolate was treated with lead acetate, and the precipitate was filtered off; the filtrate was neutralized with ammonia and precipitated with basic lead acetate. This precipitate was filtered off, and the lead removed from the filtrate with hydrogen sulphid. The lead-acetate precipitate was washed, suspended in water, and decomposed with hydrogen sulphid. The solution was bitter and contained part of the glucosid. It was very toxic. The basic lead-acetate precipitate, freed from lead with hydrogen sulphid in the same way, was not bitter, contained no glucosid, and was nontoxic. The filtrate from the lead precipitations was bitter, contained a portion of the glucosid, and was very toxic.

The marc from this extraction still contained some of the glucosid. It was dried and tested for toxicity. Small amounts fed to sheep caused nausea. Sheep 445 was force-fed small amounts of this marc moistened with water 3 times a day for 12 days, receiving in all 30 doses of marc. The animal developed the characteristic spewing and died on the twelfth day.

9. *Nauseant substances.*—(*a*) In order to investigate the question of whether the glucosid or the water-insoluble constituents of the plant are responsible for the spewing cases, 1,500 grams of the marc from number 8 was taken. This had been extracted with water to which it yielded part of its dugaldin, but still contained resins, fats, etc. It was thoroughly extracted with alcohol, which removed all the bitterness. The marc from this alcohol extraction was carefully dried and force-fed in quantity to a sheep without producing any effect. The alcohol was distilled off the extract which was green, fatty, and bitterless, the glucosid having been decomposed by the heat to which it had been subjected during the distillation. The alcohol extract was treated with chloroform, when about 75 per cent of it dissolved. The residue was fed to Sheep 447 and produced no effect. The chloroform was removed from the soluble portion and this residue was fed to Sheep 456 without effect.

(*b*) Two and one-half kilograms of the marc from number 8 was boiled two hours with 9 liters of (1 per cent) sodium-hydroxid solution and the liquid portion was pressed out. The insoluble matter was again boiled two hours with 9 liters of water, which was pressed out. Both of these liquids gelated on cooling. The residue was boiled a third time for two hours with 9 liters of water and pressed out. The mixed colates were heated to boiling and acidified with hydrochloric acid, when a curdy, green precipitate in quantity fell. This was washed thoroughly and tested for toxicity. Sheep 428 received one-fourth of it orally and showed no effect.

(*c*) The marc was extracted with dilute hydrochloric acid, which dissolved a small quantity of inorganic matter. It was then washed, dried, and tested on sheep, when it was found nontoxic.

10. *Alcohol-soluble constituents.*—Fifty-six and one-half pounds of fresh radical leaves were shredded in a meat chopper and immediately put into two 5-gallon cans, which were then filled up with strong alcohol and sealed. After two months the cans were opened. The material was packed in percolators and exhausted with alcohol. The marc from this extraction was carefully dried and tested for toxicity. A large part of it was fed to Sheep 541 for an extended period without producing any abnormal conditions.

From the alcohol extract the glucosid was isolated, but owing to much decomposition only a small amount was obtained.

11. *Experiments with the juice.*—(*a*) The juice is very toxic and small amounts of it fed daily for an extended period produce spewing cases. It was shown that all of the dugaldin might be precipitated from the juice, leaving a liquid which is not acutely toxic. Sheep 460 received on separate days three doses of 650 mils each of juice which had been precipitated with tannic acid and filtered. This produced no effect. Inasmuch as 250 mils of the untreated juice were sufficient to kill in a short time, it is evident that the tannin had removed the toxin.

(*b*) It was desired to see whether juice precipitated with tannic acid would cause the spewing cases. Accordingly three sheep, Nos. 463, 473, and 501, were given from June 25 to August 23, inclusive, daily doses of juice from 2 pounds of fresh leaves from which the dugaldin had been removed by precipitation with tannic acid. As a precaution against tannic-acid poisoning, the precipitant was added only in slight excess to the juice and, after filtering off the precipitated glucosidal tannate, the excess of tannic acid was removed by neutralizing the solution with ammonia when the tannic acid precipitated as a calcium compound. At the end of the experiment each sheep had received the detoxicated juice from 118 pounds of fresh *H. hoopesii* radical leaves. None developed spewing symptoms and all survived.

(*c*) Part of the tannic compound of the glucosid produced in these experiments was dried and fed to Sheep 482 in 2-gram doses daily (1½ pounds green leaves) for 31 days and in 4-gram doses for 25 days without producing any definite effect.

(*d*) A quantity of moist glucosidal tannate from 49.5 pounds of radical leaves was warmed with water and magnesium oxid in an attempt to decompose the compound and liberate the dugaldin. This mixture was fed in divided doses to Sheep 503 twice daily for 24 days. The animal did not become seriously sick, but the urea excretion was markedly diminished, which indicated that the glucosid was being partly absorbed. It was later found impossible to regenerate the glucosid quantitatively from its tannic acid compound, and it is believed that in these cases the larger part of it was excreted without having ever been absorbed from the alimentary tract.

(*e*) A quantity of the juice was treated with animal charcoal and after seven days had lost its bitterness and color; 500 mils of this juice (about 2 lethal doses of untreated juice) were drenched into Sheep 539 without producing any effect.

12. *Toxicity experiments with dugaldin.*—A number of animals were given doses of a solution of dugaldin in order to test the toxicity of that glucosid. The details of some representative cases are published in Table 2.

TABLE 2.—*Results of toxicity tests with dugaldin.*

Animal.	Weight.	Date.	Dose.		Material.	Effect.	Termination.	Autopsy.
			Quantity.	How given.				
	Grams.	1919.	*Ml.*					
Guinea pig 17.	500	Mar. 26	4	Orally	Solution of dugaldin.	Sick	Died	Characteristic.
Guinea pig 18.	355	do	2	do	do	do	do	Do.
Guinea pig 19.	400	do	.5	Subcutaneously.	do	do	Killed	Do.
Guinea pig 20.	425	do	.5	do	do	do	Recovered	
Guinea pig 20.		Mar. 27	1	do	do	do	do	
Guinea pig 20.		Mar. 28	.5	do	do	do	do	
Guinea pig 20.		Mar. 29	.5	do	do	do	do	
Guinea pig 20.		Mar. 30	.5	do	do	do	do	
Guinea pig 21.	380	Mar. 27	1	Orally	do	do	do	
Guinea pig 22.	365	do	1	Subcutaneously.	do	do	do	
Guinea pig 23.	250	Mar. 28	4	Orally	Solution precipitated by tannic acid.	do	do	
Guinea pig 24.	240	Apr. 9	2	Rectally	do	do	Killed	Do.
Rabbit 21	1,800	Mar. 27	1.5	Intravenously.	do	do	do	Do.

CHEMICAL SUMMARY.

1. The poisonous principle of *Helenium hoopesii* is an easily decomposed glucosid to which the name "dugaldin" has been given. It is a bitter, white, amorphous solid; soluble in alcohol; less soluble in water and chloroform; insoluble in ether, benzene, and petroleum ether.

2. Dugaldin is most poisonous when administered orally, but is also toxic when given intravenously, subcutaneously, or rectally.

3. Dugaldin may be precipitated from its solutions by tannic acid, with which it forms a sparingly soluble compound of low toxicity.

4. Helenic acid, the active principle of *Helenium autumnale,* does not occur in *H. hoopesii,* nor do alkaloids, toxic saponins, or hydrocyanic acid.

URINE EXAMINATION.

In order to determine what effect is produced in the urine following the ingestion of *H. hoopesii,* a number of 24-hour samples of urine from several sheep were examined chemically and microscopically. It was found that the total volume of the urine was diminished, in some cases enormously so. The urea excretion was also markedly diminished, while the content of ammonium compounds was much increased. Sugar was not found, but albumin frequently appeared, especially after prolonged feeding. When the feeding of *H. hoopesii* was discontinued the volume and urea content of the urine increased, while the ammonia quickly fell to normal. These results indicate a functional disturbance of the liver, since it is in this organ that the conversion of ammonium compounds to urea is largely effected. The

presence of albumin in the urine further indicates an alteration of the kidney.

Sheep 469 was fed small amounts of fresh *H. hoopesii* daily, and frequent examinations of the urine voided were made, as shown in Table 3.

TABLE 3.—*Examination of urine of Sheep 469.*

Date.	Condition of animal.	Volume.	Specific gravity.	Reaction.	Albumin.	Bile pigment.	Urea.	Biliary acids.
1919.		*Mils.*					*Grams.*	
Aug. 24	Normal	1,704	1.019	Alkaline	0	+	48.78	0
Sept. 7	Fed *Helenium hoopesii.*	905	1.027	do	Trace.	0	31.76	0
Sept. 13	do	610	1.031	do	do	+	21.11	0
Sept. 19	do	254	1.043	do	do	+	5.19	
Sept. 23	Spewing	780	1.024	Acid	0	+	4.45	0
Sept. 26		750	1.015	Alkaline	+	+	22.28	

The volume of urine voided rapidly diminished, as did the quantity of urea, but not proportionately. The amount of ammonical nitrogen could not be quantitatively determined in the field, but rough tests showed beyond question that the proportion of this was greatly increased. On September 19 the animal began to spew, when it was taken off the *H. hoopesii* ration and fed hay. The volume of urine voided immediately rose, the quantity of urea increased more slowly, and the proportion of ammonical nitrogen slowly dropped to normal.

Sheep 503 was investigated at the same time. This animal was fed a mixture of tannic-acid compound of dugaldin and magnesia. The result was an ultimate reduction in the amount of urine voided, a quick drop in urea, and an increase in ammonical nitrogen. The results of the examination are given in Table 4:

TABLE 4.—*Examination of urine of Sheep 503.*

Date.	Condition of animal.	Volume.	Specific gravity.	Reaction.	Albumin.	Bile pigment.	Urea.	Biliary acids.
1919.		*Mils.*					*Grams.*	
Sept. 6	Normal	1,525	1.018	Alkaline	0	0	32.88	0
Sept. 14	Dugaldin tannate.	2,145	1.014	do	Trace.	+	20.98	0
Oct. 1	do	230	1.052	do	0	++	8.68	0

DISCUSSION AND GENERAL CONCLUSIONS.

SYMPTOMS.

There is a definite line of symptoms in *H. hoopesii* poisoning, but they differ in detail according to the severity of the illness, and there is a fairly clear distinction between the symptoms in acute cases and those from prolonged feeding. In general the symptoms resemble those of other kinds of plant poisons, but are not so violent as in some and are not accompanied by convulsions.

Depression.—The first symptom noted in the corral cases is depression. In very mild cases this may be the only symptom noted, and probably in most range cases is overlooked. This is shown in the attitude of Sheep 314. (Pl. I, fig. 5.)

Pulse.—In most cases the pulse is weak, irregular, and somewhat rapid. Of these characteristics the irregularity is most noticeable, and in mild cases this and depression may be the only symptoms noted. Of course in range cases this is never recognized.

Weakness.—Accompanying the depression and weak and irregular pulse is a general weakness, which is more pronounced in the prolonged cases. This is shown in Sheep 374 (Pl. II, fig. 1) and still more clearly in Sheep 421 (Pl. I, figs. 1, 2, 3, 4, 5, and 6). In some of the acute cases this weakness does not appear at all.

Restlessness.—Both in the early and later stages of the sickness, the animals generally exhibit marked restlessness. If they are strong enough to stand on their feet they will remain standing but a short time, when they will lie down and then very soon get up again and move about in an uneasy way.

Stiffness.—During the sickness a peculiar stiffness in gait frequently is noticed. This accompanies the weakness, though it is not a result simply of weakness, and may be considered somewhat characteristic of the intermediate stages.

Temperature.—There are no marked changes in the temperature, and it remains practically normal during the period of illness.

Respiration.—The respiration is quickened when the animal attempts to get up on its feet, and is also more rapid during the acute stages of the sickness. There are no peculiarities of respiration which can be considered as characteristic of *H. hoopesii* poisoning.

Salivation.—Salivation occurred in many of the force-fed animals and in some of those poisoned by prolonged feeding. In some cases the salivation resulted in profuse frothing at the mouth. Doubtless this was due in some measure to mechanical irritation caused by the method of forced feeding, but this was not the complete explanation; salivation may be considered as a common symptom in the forced-feeding cases and as a symptom which occasionally occurs in chronic cases. Sheep 358 (Pl. II, fig. 2) is a good example of a salivated animal.

Nausea.—Nausea was exhibited in many of the animals; it did not however, always result in vomiting. In some of the acute cases vomiting did not take place, although it did in some of those in which repeated forced feeding were made. Generally speaking, in the prolonged cases vomiting, or "spewing," as it is called by the sheepmen, is the most prominent symptom of *H. hoopesii* poisoning. In range animals it is practically the only symptom which is noticed by the

herders. It is not unusual, when a flock of sheep has been feeding upon a *H. hoopesii* area, to see large numbers of them throwing up their heads and vomiting. The large sheep in the foreground of figure 3, Plate II, shows the typical attitude of one of these animals in a flock feeding upon the range, and figure 4 of Plate I shows the attitude assumed by a corral force-fed animal in the act of vomiting. Sheep 420, which became ill from prolonged feeding, is shown in Plate II, figure 4, in an attitude produced by nausea. The pictures of Cattle 827 (Pl. II, figs. 5 and 6) show nausea and vomiting.

This tendency to vomit may continue for a prolonged period after the feeding upon *H. hoopesii* has been stopped. The experiences with the animals in 1917 may be quoted as giving a definite idea of the frequency of this symptom. Out of 12 prolonged feedings and 2 repeated forced-feeding cases in this year vomiting occurred in 8 feedings and in 1 of the repeated forced-feeding cases. Of the 8 acute cases in this year only 1 showed a tendency toward vomiting.

Coughing.—Many of the poisoned sheep were noticed to be frequently coughing. This was particularly noticeable in the animals poisoned upon the range. It is probably due to mechanical irritation caused by material from the stomach getting into the larynx.

Bloating.—Bloat occurred in some of the experimental animals in both acute and chronic cases, and when it occurred was sometimes accompanied with the belching of gas from the stomach. Bloating can not be considered as a usual symptom of the experimental animals. In range cases, however, most of the spewing cases apparently are bloated.

Trembling.—Trembling was noticed in a number of the cases, but can hardly be considered a characteristic symptom, as it probably results simply from the general weakness of the animal.

Diarrhea.—In some of the animals diarrhea followed the severe stages of the sickness and was noticeable before complete recovery took place. It was not, however, a usual symptom, and neither it nor constipation can be considered as characteristic of *H. hoopesii* poisoning.

Most Prominent Symptoms.

The especially prominent symptoms, then, of *H. hoopesii* poisoning are general depression, weak and irregular pulse, weakness, and nausea, followed by more or less chronic vomiting. Vomiting is not a characteristic of the acute cases and does not always appear in the chronic cases. Apparently the chronic cases of sheep can be divided into two types—one characterized by extreme weakness with rapid and irregular pulse, and the other with the added symptom of vomiting.

Death comes on quietly and is not accompanied by convulsions. Plate I, figure 6, shows Sheep 314 in the last stages.

AUTOPSY FINDINGS.

In 1915 there were 6 autopsies on sheep, 7 in 1916, 7 in 1917, and 1 in 1918. In the results of these autopsies no uniform picture was presented which could be considered as characteristic of *H. hoopesii* poisoning. In some there were congested lungs and kidneys, but this condition was by no means found even in the majority of cases. Generally speaking there was, however, distinct congestion of parts of the alimentary canal. In nearly all cases there was congestion of the duodenum and ileum, and in most of them congestion of the walls of the stomachs. In some cases this congestion was found in the cecum and even in the rectum, but this was not ordinarily the case. It can hardly be said that the autopsies gave any diagnostic characteristics of *H. hoopesii* poisoning.

In 4 of the 5 acute cases on which autopsies were held a considerable mass of serous coagulum was found on or near the rumino-reticular groove. This, doubtless, was caused by the marked effect of the *H. hoopesii* poison upon the circulatory system, as explained in the discussion of the pathology which follows.

MICROSCOPIC PATHOLOGY OF H. HOOPESII POISONING.

The pathological changes occurring in the tissues of sheep poisoned with *Helenium hoopesii*, or its extracts, vary with the type of the case and the method of administering the material.

Liver.—In all types of cases the liver is affected, the hepatic cells varying in condition. In acute cases the liver cords may appear compressed from edema, and the hepatic cells themselves often contain large, irregular-shaped, open spaces. In other cases the hepatic cells are swollen so as to obscure the capillaries. In the chronic type, mild cloudy swelling or fatty degenerative changes may occur. In one case interstitial hepatitis, and in another a well-marked small-cell infiltration occurred. Bile ducts are very frequently catarrhal or sometimes badly broken down.

The quantity of blood varies between wide limits, a few cases being severely congested, while in others very little blood is present.

In all cases the blood stream in the liver is affected, this being seen best in the central lobular and sublobular veins. In many such veins, besides normal erythrocytes, there are leached or degenerate erythrocytes, granular material, areas of numerous leucocytes, and sometimes fibrous material. Hepatic cells sometimes are floating in the blood stream. These bodies may or may not be attached to the wall of the vein. While some of them may be formed about the time of death when the blood flow becomes very sluggish, their structure would indicate that they are thrombi.

The thrombi and the edematous, or swollen, liver cells occasion some resistance to the blood flow, and sometimes cause the mesenteric veins, the spleen, and the pancreas to be more or less congested.

Lungs.—There is no more uniformity of condition found in the lungs than in the liver. As a rule the acute cases have congested lungs, the capillaries in some being greatly distended, and there is much blood in the arteries. In some cases the pronounced capillary congestion has led to a transudation of serum, and some diapedesis of erythrocytes. Generally, too, there is a marked catarrhal condition of the bronchi, which may contain desquamated epithelial cells and red blood corpuscles. Alveoli in places contain coagulated serum.

The blood contained in and sometimes filling the arteries is similar in condition to that seen in the veins of the liver, except that normal leucocytes are rarely seen.

The lungs of the three chronic cases examined were found to be diseased. In the sections of the lung of Sheep 319 there were necrotic areas. The alveoli surrounding such areas contain numerous leucocytes and some exfoliated epithelial cells. Some small blood vessels were engorged. In the lung of Sheep 348 there were areas of serous transudation, which, with the thickened alveolar walls and marked invasion of leucocytes, obliterated many alveoli. This condition probably results from spewed material being drawn down the trachea and accounts for the cough so common in old "spewers."

Sheep 437, an old spewer killed later with *Asclepias galioides*, had lung adhesions and necrotic areas. In sections of the least diseased parts of the lung there was an excess of connective tissue.

Kidneys.—The kidneys are equally variable in their pathological condition. In none of the cases examined was there severe congestion. In all those studied there was an edematous condition of the capsule of Bowman, the edema separating the folds of the glomeruli and leaving a large clear area between the glomeruli and the capsule wall. This is sometimes accompanied with a small quantity of stainable material resembling degenerated cytoplasm. In most of the cases examined the cells of some portions of the convoluted tubules had undergone degenerative changes. Some are swollen, while others are beginning to disintegrate the granular material lying in the lumina.

Alimentary tract.—The most pronounced change occurred in the alimentary tract of the acute cases, the exact portion varying with the method of administering the material. In four sheep—Nos. 338, 314, 331, and 413—which died from single forced feedings, the most severe changes were in the rumen and reticulum near the opening of the esophagus. In one sheep which was drenched with an extract the severe changes occurred in the walls of the abomasum, colon, and rectum, with less severe changes in the small intestine.

The changes found in the rumen and reticulum walls are of the same character, consisting of a very pronounced serous infiltration

and an invasion of great numbers of leucocytes. The serum which has become coagulated is in all tissues, pushing the tissue elements apart and greatly thickening the walls. It is a portion of this serous transudate which was found in the serous coat in the neighborhood of the rumino-reticular groove. In these cases, with one exception, erythrocytes are not abundant, though vessels just beneath the mucosa are distended.

The leucocytes are very abundant in the submucosa in places and are grouped, resembling lymph nodules. These areas may extend up through the muscular layers and into the serosa. The cells of these areas differ from those of lymph nodules. They are apparently more or less degenerated, but on the whole more resemble polymorphonuclear leucocytes than the cells of the lymph nodules. The abomasum wall is edematous, and in areas in the mucosa is sometimes hemorrhagic.

Sheep 451, which was given an extract of *Helenium hoopesii* in a drench, differed from the foregoing in that the point of irritation was mainly in the abomasum, colon, and rectum. The walls of these portions of the alimentary tract were highly congested, the congestion being accompanied by edema and hemorrhage. This condition was most pronounced in the mucosa in which layer degenerative changes had occurred. The abomasum wall was most thickened and the serum was more coagulated there than elsewhere. The condition differed from that found in the first and second stomachs of the force-fed cases in that there was not so marked an invasion with leucocytes; more blood was present, and the serum was less coagulated. In this case the duodenum and jejunum were quite edematous but not severely congested. No sections of the ileum were made, though the autopsy report shows it to have been inflamed in portions.

This inflammation of portions of the alimentary tract does not occur in chronic cases. There may be mild congestion and some edema present in the abomasum and ileum, but this is not severe. In many places in the digestive tract the erythrocytes of the venous blood take the eosin stain much less strongly than those in the neighboring arteries. This, taken with the finding of degenerated erythrocytes in the veins of the liver, indicates a certain amount of direct action of the toxin on the red blood corpuscles. That this is not severe in chronic cases has been shown by hemoglobin tests on sick as compared with normal sheep.

Tissues from a number of guinea pigs killed or made sick on extracts of *Helenium hoopesii* were studied and agreed fully with the findings on sheep tissues.

Dugaldin, then, appears to be highly irritant and to be absorbed in any portion of the alimentary tract of the ruminant. It is proba-

ble, however, that to be absorbed in the rumen or reticulum it must be in sufficient concentration to damage the epithelium.

TOXIC DOSE FOR SHEEP.

In determining the toxic dose a distinction should be made between poisoning by a single administration of the plant and the toxic result of prolonged feeding. It was found that no animal would eat enough in a single day to produce symptoms, but by the use of the balling gun it could be compelled to swallow enough to produce intoxication or death. Moreover, the whole aerial part of the plant including stems, leaves, and flowers was used with some animals while in other cases use was made of stem leaves, radical leaves, flowers or stems, leaves, and fruit.

Toxic dose of whole plant, including leaves, stems, and flowers when fed.—Eight sheep were used in the feeding of the whole plant in 1915 and two in 1916. Table 5 shows the result:

TABLE 5.—*Summary of feedings of leaves, stems, and flowers.*

Animal.	Total fed per hundred-weight of animal.	Total days fed.	Average daily feed per hundred-weight of animal.	Days before sick.	Quantity per hundred-weight of animal to produce sickness.	Daily average to produce sickness.	Result.
1915.	*Pounds.*	*Days.*	*Pound.*	*Days.*	*Pounds.*	*Pounds.*	
Sheep 316	2.19	1	2.19				Not sick.
Sheep 319	82.468	21	3.9	21	75.3	3.1	Died.
Sheep 326	43.299	28	1.546				Not sick.
Sheep 328	74.713	19	3.932	19	74.713	3.9	Sick.
Sheep 329	32.865	17	1.933				Not sick.
Sheep 333	28.372	24	2.182	24	28.372	1.182	Weak.
Sheep 344	2.469	3	.835				Not sick.
Sheep 346	80.311	59	1.361	23	35.7	1.5	Symptoms.
1916.							
Sheep 386	77.166	52	1.434	20	37.579	1.879	Very sick.
Sheep 385	49.074	36	1.363	23	34.626	1.505	Do.
Average				21.6	47.715	2.17	

In all the cases of 1915 except sheep 316 the animals were given only the *H. hoopesii*. In the cases of 1916, hay was fed with the plant.

Averaging these cases, a daily feeding of 2.17 pounds continued 21.6 days produced sickness or death. The limits of the daily dosage, however, were rather wide, varying from 1.18 pounds in Sheep 333 to 3.9 pounds in Sheep 328. There was nothing in the conditions of the experiments to explain this wide divergence.

TOXIC DOSE FOR CATTLE.

Cattle 824 was made sick in 21 days, receiving in that time 52.6 pounds while Cattle 827 was made sick in 39 days, receiving in that time 48.32 pounds. The two cases average in 30 days of feeding with

a daily dosage of 1.68 pounds per hundredweight of animal. This, it will be seen, does not differ materially from the average obtained for sheep, so that the inference is a reasonable one that *H. hoopesii* is about equally poisonous to sheep and cattle.

ACUTE CASES.

Table 6 gives a summary of the animals to which the green plant was given by forced feeding in one day in order to produce acute cases.

TABLE 6.—*Summary of forced feedings of green leaves in one day which produced intoxication.*

Animal.	Number of feedings.	Quantity fed per hundredweight of animal.	Time from end of feeding to symptoms.	Result.
1915.		*Pounds.*	*Hours.*	
Sheep 315	2	2.646	6¼	Sick.
Sheep 332	2	2.846	(1)	Do.
Sheep 340	3	2.645	2	Do.
1916.				
Sheep 393	2	2.509	3¼	Do.
1917.				
Sheep 424	1	2.306	8½	Very sick.
Sheep 432	1	2.501	5½	Sick.
Sheep 428	1	2.299	24	Symptoms.
Sheep 444	1	2.217	6½	Do.
1918.				
Sheep 461	1	2.835	31½	Sick.
Average		2.494		

[1] Immediate effect.

The average dosage in the table above was 2.494 pounds, with a minimum limit of 2.217 pounds and a maximum of 2.846 pounds. In general it may be stated that 2.5 pounds of green leaves fed in one day may produce intoxication. It should be noticed, however, that none of these feedings resulted in death. Reference to Table 1 will show that—

Sheep 320 received 2.79 pounds without effect.
Sheep 318 received 2.646 pounds without effect.
Sheep 347 received 2.756 pounds without effect.
Sheep 479 received 2.473 pounds without effect.

It is recognized that there is some difficulty in noting slight symptoms and that some of these animals may have been affected by the plant, although no positive symptoms appeared. It is fair, however, to draw the inference that while 2.5 pounds may be considered as the toxic dose of the green plant in acute cases, it does not follow that all animals receiving this quantity in a single day will be poisoned.

Comparing these results with those in Table 8, showing the effect of feeding green leaves in the corrals, it is interesting to note that the average quantity, about 2.5 pounds, necessary to produce acute cases, is only slightly greater than the average quantity, fed in the corrals for three weeks, which produced chronic cases—namely, 2.2 pounds. While as large a quantity as 3.143 pounds has been fed daily for 22 days before producing intoxication, it is evident that when the feeding is not made in a single dose, but is continuous and spread over a considerable period of time, much of the toxic principle must be eliminated.

Continued Forced Feeding.

In some animals the forced feeding of green leaves was continued in smaller doses for several days. The following table shows those in which positive results were obtained:

Table 7.—*Forced feedings of green leaves, in two or more days, which produced intoxication.*

Animal.	Days fed.	Number of feedings.	Quantity fed per hundredweight of animal.		
			Total.	Daily average.	Result.
1915.	*Days.*		*Pounds.*	*Pounds.*	
Sheep 355	3	4	4.001	1.33	Died.
Sheep 358	3	5	4.139	1.379	Sick.
Sheep 327	7	12	7.936	1.134	Do.
Average	$4\frac{1}{3}$		5.359	1.281	

According to Table 7, an average daily feeding of 1.281 pounds continued for $4\frac{1}{3}$ days produced sickness or death, or, in round numbers, $1\frac{1}{4}$ pounds given daily for 4 or 5 days produced intoxication. As compared with voluntary feeding upon leaves (p. 33) these force-fed animals were poisoned on a smaller dosage and in less time.

TOXICITY OF LEAVES OF PLANT.

It is to be presumed that sheep on the range, when eating *H. hoopesii* feed mainly on the leaves. It is of special interest, therefore, to know the dosage of leaves that will produce sickness or death. A large number of feeding experiments were carried on, and Table 8 summarizes the results of corral feeding of green leaves.

TABLE 8.—*Summary of corral feeding of green leaves.*

Animal.	Days fed.	Quantity fed per hundredweight of animal.		Days before sick.	Quantity fed per hundredweight of animal to produce sickness.		Result.
		Total.	Daily average.		Total.	Daily average.	
1915.	*Days.*	*Pounds.*	*Pounds.*	*Days.*	*Pounds.*	*Pounds.*	
Sheep 323	27	34.058	1.261	.....	.....	.....	Symptoms.
Sheep 325	4	3.175	.794	.....	.....	.....	Not sick.
Sheep 330	9	7.805	.967	.....	.....	.....	Do.
Sheep 339	20	27.014	1.351	.....	.....	.....	Symptoms.
Sheep 341	15	21.519	1.434	.....	.....	.....	Not sick.
Sheep 352	5	2.57	.514	.....	.....	.....	Do.
Sheep 357	13	15.192	1.169	.....	.....	.....	Do.
Sheep 360	9	9.091	1.01	.....	.....	.....	Do.
1916.							
Sheep 380	54	113.82	2.1	25	64.583	2.583	Died.
Sheep 384	56	120.3	2.149	29	73.544	2.536	Very sick.
Sheep 394	21	49.65	2.364	15	37.589	2.506	Died.
Sheep 377	26	62.577	2.4	16	40.491	2.53	Very sick.
Sheep 389	33	78.697	2.385	17	43.662	2.568	Do.
Sheep 333	30	51.464	1.715	24	43.008	1.792	Do.
Sheep 339	33	64.861	1.965	18	45.625	2.535	Do.
Sheep 357	28	50.219	1.794	25	43.296	1.732	Sick.
Sheep 401	30	51.16	1.705	26	47.969	1.845	Very sick.
Sheep 326	30	37.427	1.248	.....	.....	.....	Not sick.
Sheep 403	8	2.112	.264	.....	.....	.....	Do.
1917.							
Sheep 411	16	51.145	3.196	12	36.641	3.053	Very sick.
Sheep 412	29	64.091	2.210	18	36.818	2.045	Do.
Sheep 423	36	53.107	1.475	33	47.469	1.438	Do.
Sheep 418	28	62.013	2.215	26	55.844	2.148	Do.
Sheep 416	34	65.566	1.928	19	38.433	2.023	Do.
Sheep 419	32	60.050	1.877	20	28.894	1.445	Died.
Sheep 420	33	42.731	1.295	18	27.099	1.505	Sick.
Sheep 448	52	92.148	1.772	47	69.977	1.489	Symptoms.
Sheep 437	19	38.419	2.022	13	25.368	1.951	Very sick.
Sheep 421	23	47.925	2.083	19	43.281	2.278	Do.
1918.							
Sheep 486	23	53.061	2.307	16	44.898	2.806	Sick.
Sheep 490	23	70.370	3.060	22	69.136	3.143	Do.
Sheep 506	33	79.167	2.399	26	56.150	2.16	Do.
Sheep 467	40	53.704	1.343	.....	.....	.....	Not sick.
Sheep 481	18	56.250	3.125	18	56.250	3.125	Sick.
Sheep 492	21	36.283	1.728	.....	.....	.....	Not sick.
Sheep 469	25	49.519	1.981	16	36.058	2.254	Sick.
Average	26	49.395	1.795	21.58	46.340	2.228	

It is seen from the averages of this table that a sheep will be poisoned by eating 2.228 pounds daily for 21.58 days, getting in this time a total of 46.34 pounds. These figures must not be construed, however, as giving very exact limits, for the time necessary to produce intoxication varies from 12 to 47 days, and the daily dosage from 1.438 to 3.143 pounds. Moreover, there is no clear relation between the quantity fed and the time necessary to produce results. In some cases it was necessary to continue the smaller dosage a longer time, as in Sheep 448 and Sheep 423; but Sheep 420 had nearly the smallest daily feeding and became sick in 18 days. Neither in the three cases which ended fatally is it clear that it was because of greater feedings or longer period of experimentation.

TOXICITY OF FLOWERS.

Table 9 gives the results obtained when flowers of *H. hoopesii* were fed in the corrals:

TABLE 9.—*Summary of corral feeding of flowers.*

Animal.	Days fed.	Quantity fed per hundredweight of animal.		Days before sick.	Quantity fed per hundredweight of animal to produce sickness.		Result.
		Total.	Daily average.		Total.	Daily average.	
1915	*Days.*	*Pounds.*	*Pounds.*	*Days.*	*Pounds.*	*Pounds.*	
Sheep 343	6	8.14	1.36	.....	.....	.....	Not sick.
Sheep 357	9	15.936	1.77	.....	.....	.....	Do.
1916							
Sheep 378	46	89.643	1.949	34	66.768	1.964	Sick.
Sheep 373	49	72.055	1.471	19	30.303	1.595	Very sick.
1917							
Sheep 446	37	84.082	2.272	22	47.755	2.171	Do.
Average	.....	.....	.....	25	48.275	1.943	

These results show that the toxicity of the flowers is practically the same as that of the leaves.

TOXICITY OF STEM LEAVES.

The summaries of forced feeding of green leaves, in Tables 6 and 7, were of experiments in which radical leaves were used. For the purpose of comparison, forced feedings of stem leaves were made in 3 cases, as shown in Table 10.

TABLE 10.—*Summary of forced feedings of stem leaves.*

Animal.	Days fed.	Number of feedings.	Quantity fed per hundredweight of animal.		Result.
			Total.	Daily average.	
1915	*Days.*		*Pounds.*	*Pounds.*	
Sheep 331	1	1	2.645	2.645	Died.
Sheep 340	1	3	2.645	2.645	Sick.
Sheep 347	1	2	2.756	2.756	Not sick.

With these animals the feeding was given in one day. Comparing the results with Table 6, in which are summarized the feedings of radical leaves in one day, it is evident that the dosage is practically the same, not far from 2.5 pounds, with a considerable margin of possible variation.

COMPARATIVE TOXICITY OF DIFFERENT PARTS OF THE PLANT.

Summarizing the averages of the feedings of different parts of the plant we get the following:

Whole plant produced sickness when 2.17 pounds was fed daily for 21.6 days.
Leaves produced sickness when 2.228 pounds was fed daily for 21.58 days.
Flowers produced sickness when 1.943 pounds was fed daily for 25.1 days.

The difference in the toxicity of the different parts of the plant therefore is negligible; also the comparison just mentioned shows that there is practically no difference between the radical leaves and stem leaves.

EFFECT OF DRYING ON TOXICITY OF LEAVES.

A few feedings were made to determine whether drying of the leaves caused any loss of toxicity. Table 11 shows the results.

TABLE 11.—*Summary of forced feeding of dry leaves.*

Animal.	Days fed.	Number of feedings.	Quantity fed per hundredweight of animal (estimated as green plant).		Result.
			Total.	Daily average.	
1916	*Days.*		*Pounds.*	*Pounds.*	
Sheep 376	1	2	3.475	3.475	Symptoms.
1917					
Sheep 409	1	1	2.301	2.301	Do.
Sheep 439	4	3	11.305	2.826	Sick.
Sheep 422	5	5	10.776	2.155	Symptoms.

Averaging the two cases fed in one day, the toxic dose of dry leaves in terms of green plant is 2.888 pounds. Averaging the two cases given prolonged feeding, 2.49 pounds daily for 4½ days produced sickness.

As it is shown in Table 6 that the toxic dose of green leaves given in one day is 2.494 pounds, and in Table 8 that 1.281 pounds of green plant given for 4⅓ days produce sickness, it appears that the dry plant given by forced feedings is not so toxic as the green plant.

The prolonged feedings of the dry plant, however, gave somewhat different results. The cases are listed in Table 12:

TABLE 12.—*Summary of prolonged feedings of dry leaves.*

Animal.	Days before sick.	Quantity per hundredweight of animal to produce sickness.		Result.
		Total.	Daily average.	
1916	*Days.*	*Pounds.*	*Pounds.*	
Sheep 392	15	34.011	2.267	Very sick.
Sheep 395	18	21.712	1.206	Symptoms.
Sheep 374	14	43.043	3.074	Very sick.
Sheep 375	15	28.467	1.898	Sick.
1918				
Sheep 471	21	44.094	2.1	Symptoms.
Sheep 472	16	34.45	2.15	Sick.
Average	16.5	34.296	2.116	

The results show that an average daily feeding of dry leaves of 2.116 pounds continued for 16.5 days produces sickness. On page 33 it is shown that an average daily feeding of 2.228 pounds of green leaves produces sickness if continued for 21.58 days. Judging by these figures alone it would appear that the dry plant is more toxic than the green. After making allowances for the small number of cases and the necessary inaccuracies of the detail of the experiment, it seems probable that there is no material difference in toxicity between the green and dried plant. It should be noted in this connection, however, that the dry plant used in the experiments had been collected and dried under cover and that this conclusion might not apply to the plant dried standing on the range.

SEASONAL VARIATION IN TOXICITY OF THE PLANT.

For practical purposes it is desirable to know whether the plant is especially toxic at any particular season. Part of the experiments of 1917 and 1918 can readily be divided into two groups, one occurring in June and early July, and the other in late July, August, and September.

In June, 1917, Sheep 424, 415, 413, 432, and 428 were given single forced feedings with an average dose of 2.358 pounds, three being made sick and two dying. Sheep 444, on September 13, showed symptoms from a forced feeding of 2.217 pounds. The difference between the two groups evidently is very slight.

The sheep receiving prolonged feedings of leaves in 1917 can be divided into three chronological groups, as shown in Table 13.

TABLE 13.—*Seasonal variation in toxicity of plant.*

Animal.	Date of feeding.	Days to produce sickness.	Quantity per hundredweight of animal to produce sickness.		Result.
			Total.	Daily average.	
	1917.	*Days.*	*Pounds.*	*Pounds.*	
Group 1:					
Sheep 411	June 8 to 23	12	36.641	3.053	Very sick.
412	June 8 to July 6	18	36.818	2.045	Do.
423	June 8 to July 13	33	47.469	1.438	Do.
418	June 3 to July 5	26	55.844	2.148	Do.
Average		22.25	44.190	2.171	
Group 2:					
Sheep 416	July 6 to Aug. 8	19	38.443	2.023	Do.
419	July 8 to Aug. 8	20	28.894	1.445	Died.
420	July 8 to Aug. 9	18	27.099	1.505	Sick.
Average		19	31.479	1.657	
Group 3:					
Sheep 448	July 27 to Sept. 16	47	69.997	1.489	Symptoms.
437	Aug. 21 to Sept. 8	13	25.368	1.951	Very sick.
421	Aug. 27 to Sept. 18	19	43.281	2.278	Do.
Average		26	46.209	1.902	

If Table 13 is taken at its face value, we must consider the plant as most toxic in midsummer and more toxic in September than in June.

It may be seen from Table 1 that in 1918 four sheep were poisoned by feeding in June and July, while only one sheep, No. 469, was poisoned by feeding late in the season; this from August 26 to September 19 received 36.058 pounds—an average daily feeding during 25 days of 1.442 pounds. In these cases, again, the dosage of the latter part of the season was rather smaller than it was earlier.

While the numbers of cases in different parts of the year are too small to permit of reliable averages, it seems that there is an apparent tendency to slightly greater toxicity in the latter part of the season. This probably is explained by the greater quantity of water contained by the plant early in the season. In general, it may be stated that there is no marked seasonal variation in toxicity.

PERMANENT EFFECT PRODUCED BY THE POISON.

It was noticed in the corral cases that the effect of *H. hoopesii* poison was continued for a prolonged period, and that complete recovery, if it occurred at all, was slow in appearing. People who handle sheep in the *H. hoopesii* region have a theory that a spewing sheep never completely recovers. It is stated that if a band of sheep is brought from the outside to a *H. hoopesii* range, there are comparatively few cases the first year, more the second, and still more the third. This is explained by supposing that the effects of *H. hoopesii* feeding continue over from year to year. In connection with the experiments at the Salina station, some sheep were kept for two or more years and notes made in regard to the outcome of cases that were poisoned and apparently recovered. The results appear to show quite conclusively that the effect of *H. hoopesii* poison may be permanent; that sheep once affected by this plant are likely to succumb more quickly to a succeeding feeding, and, even if they apparently recover, are likely to prove worthless.

HELENIUM HOOPESII A CUMULATIVE POISON.

As previously shown, if about 2 pounds of *H. hoopesii* leaves are fed daily for about 20 days, sickness is produced, although a considerably smaller amount may have a toxic effect. For instance, in 1918 Sheep 469 was made sick on a daily feeding of 1.6 pounds, while on the other hand 1.5 pounds was fed daily for more than 20 days without producing any effect. If less, however, than 1.5 pounds a day is fed, positive symptoms do not develop. For example, Sheep 467 ate on the average of 1.3 pounds a day for 40 days without showing any distinctive symptoms. It will be remembered also that a single day's forced feeding of 2.494 pounds produced toxic symptoms.

It seems clear that if the daily feeding is less than 1.5 pounds, the toxic substance is eliminated to such an extent that no injurious effect follows. If, however, the daily ration is between this limit and a toxic dose of one day's feeding, the effect of the plant accumulates. It should be added that there is every reason to think, as stated elsewhere, that the poisonous principle of *H. hoopesii* produces a permanent effect upon the animal, and, when it is stated that the poisonous substance is eliminated, it is by no means certain that some effect has not been produced. This has a distinct bearing on range poisoning, for it is probable that sheep that feed freely upon the range show the effect of eating *H. hoopesii* only after many days or perhaps weeks of feeding.

REMEDIES.

Three classes of remedies were tried:

1. On the assumption that increase of the processes of elimination would be of assistance in reducing the effects of the *Helenium hoopesii* poisoning, a number of substances were used, including Epsom salt and Epsom salt combined with strychnin, linseed oil, and linseed oil combined with glycerin, linseed oil combined with turpentine and strychnin, sodium cacodylate, paraffin oil, and paraffin oil combined with strychnin. Most of the animals treated with these agents showed improvement. It was not clear, however, that the improvement was due to the remedy.

2. It having been found by chemical examination that the toxic agent of *H. hoopesii* is a glucosid, and that this is precipitated from the plant juice by tannic acid, tannic acid was used experimentally as a preventive of poisoning. Two sheep (Nos. 486 and 506) were fed upon the plant and received daily a drench of tannic acid. No. 486 was fed upon the radical leaves from June 13 to July 5. From June 18 to July 10 it received twice daily a drench containing one-half gram of tannic acid. On June 28, or the sixteenth day of feeding, the sheep started spewing. During the remainder of the experiment the sheep continued to spew and showed other symptoms of *H. hoopesii* poisoning. This sheep was poisoned in 16 days on 44.9 pounds, or an average of 2.8 pounds per day. Sheep 506 was fed upon radical leaves from June 13 to July 15. Until June 20 it ate very little of the plant, but at that time began to eat more freely. From June 18 to July 15 she was drenched twice daily with 1 gram of tannic acid in solution. The animal showed positive symptoms of poisoning in 26 days after eating 56 pounds, or a daily average of 2.16 pounds. Feeding was continued for 7 days following the symptoms, and the tannic-acid treatment for a considerable time longer. In these two cases the tannic acid appeared to have no beneficial effect.

Two sheep (Nos. 490 and 467) were fed on this plant and during the feeding a mixture of tannic acid and salt was kept in the pen. Sheep 490 showed symptoms in 22 days after eating 69 pounds of the plant. Sheep 467 after 40 days feeding with a daily average quantity of 1.34 pounds showed no symptoms. This animal, however, did not eat the plant freely and did not get enough during the period of feeding to produce toxic symptoms. Neither of the sheep ate very much of the tannic acid and salt mixture. In the case of these sheep, as of the other two, there was no evidence of any beneficial effect from the tannic acid.

3. Because of the general practice on the Fishlake National Forest of moving spewing sheep to a lower level, where they could graze on browse, and as the browse consisted largely of oak and service berry, it was thought worth while to try out the effect of feeding these plants to animals that were receiving *H. hoopesii* leaves. This was tried with several animals, but with no resulting benefit. From these experiments it seems probable that the benefits which the sheepmen say follow the removal of the animals to browse result not from the effect of the browse but from the removal of the animals from the sneezeweed and the consequent change of forage.

The general result of these experiments on remedies was discouraging, and it can only be said that at the present time no effective remedies are known which can be used for *H. hoopesii* poisoning.

TREATMENT OF PLANT ON THE RANGE.

Possibility of Exterminating Helenium hoopesii.

The question has been asked, Is it not possible by digging to rid the range of *H. hoopesii?* In order to determine this somewhat exactly, an area where the plant was fairly thick was measured off and two men were set to work—one with a hoe and the other with a spade—to dig up the plant. The plant was not simply cut off, but was dug up and the roots exposed to the sun. On the basis of the work done by these two men it would require 81 hours and 20 minutes to clear an acre. This at the present price of labor on the range would cost at least $30 an acre. This cost evidently is prohibitive.

The area was cleared on September 8, 1918, and was kept under observation during the season of 1919. When examined on September 19, 1918, it was found that the plants had been almost entirely killed. A few small plants had been overlooked and a considerable number of very small plants were found which probably started after the area was dug over.

The plot was examined again August 4, 1919, when it was found that the few plants which were growing were for the most part from seedlings. On the whole area of 4 square rods, 14 flower stalks were

counted. Very little grass had come in, and the area, which was on a slight incline, had been somewhat washed by the rains.

On July 27, 1920, seventy-two flowering stems of *H. hoopesii* were counted, and besides there was a considerable number of small plants from which no flowering stems had grown. Nineteen bunches of *Symphoricarpos* had come in, and there were a few grass plants and dandelions, with considerable chickweed. On August 18 the *H. hoopesii* plants were cut out with a hoe, the work requiring 16 hours and 40 minutes per acre. A sharp hoe was used, so that many of the plants were cut out rather than pulled out, the cutting being done 2 or 3 inches below the surface of the ground. When the ground was examined again September 11, 1920, it was found that a few more seedlings had started, and that there was a fairly vigorous growth from the cut plants. In these cut plants the growth was generally from buds which had started near the cut surface, but in some of them adventitious buds were found upon the larger roots well below the surface. Apparently buds may appear from almost any part of the root which remains in the ground.

Time at the rate of 30 hours per acre was spent in going over the patch again with a hoe, especial pains being taken to remove the plants so that the roots should be exposed upon the surface. Of course, many of the smaller roots were torn off and left in the ground.

The patch will be kept under observation for a longer time, but it is evident that the destruction of the plant on the range by digging is not likely to be a success. The plant grows so thickly that in order to clear a given area it is necessary to dig up almost the whole surface, so that if a range were to be cleared it would be necessary not only to dig up the plant but to reseed the area, as after the digging it would be left almost devoid of vegetation. The great expense of this work would make this method of clearing the range a practical impossibility.

Effect of Cutting Off with a Scythe.

In order to determine what effect would be produced by repeated cutting down of the aerial parts of the plant an area was staked off July 25, 1918, and a similar area by its side as a control. On this date the plants were cut with a scythe from the experimental area.

An examination of the area, September 9, 1918, showed the plants apparently in a more thrifty condition than those on the control patch. More new leaves had been put forth on the cut plants than upon those that had not been injured. Cutting off the tops appeared to have a stimulating effect upon the plants. This is perhaps what should have been expected, for, as stated above, adventitious buds readily start not only from the crown but also from the roots, and these buds doubtless grow more numerously because of the cutting off of the top.

The scythe cutting was repeated in the summers of 1919 and 1920, with no change in results.

It seems clear that scythe cutting has no deleterious effect on the growth of the plant.

Effect Produced on the Plant by Restriction of Grazing.

Inasmuch as it is recognized that the present abundance of *H. hoopesii* on some ranges is correlated with the overgrazed condition, it is desirable to determine what effect would be produced by removing grazing animals for a period. The *H. hoopesii* is not particularly palatable to any grazing animals. Cattle very rarely eat it even when the range is reduced to an almost pure stand of this plant. The sheep eat it only after most of the desirable forage has been removed. Under such circumstances the *H. hoopesii*, which is a rank-growing plant, takes almost complete possession of the range. If the grazing animals were removed and the range allowed to reseed itself, it might be possible that by the growth of grasses and weeds the *H. hoopesii* would be gradually diminished in abundance. In order to test this possibility, a locality was selected on an evidently overgrazed range where the *H. hoopesii* was very abundant, and about one-fourth of an acre was fenced off, the plan being to keep it under observation for a term of years. This area was on a very heavily grazed cattle range on which little remained except the *H. hoopesii*, and that was very abundant.

The land was fenced off on September 16 and 17, 1915, and on September 24 half of the plot was sowed to grass seed. Timothy was seeded on a part of this and orchard grass on the rest. The grass seed was scattered broadcast and was not raked in.

The area was visited on June 23, 1916. It was found that the fence had been broken down during the winter and the ground more or less trampled. There was no evidence that any of the grass seed which had been sowed had germinated; in fact there was more grass on the part of the plot which had not been sown than on the remainder. The general appearance of the tract was very much better than that of the ground outside of the fence. Evidently considerable grass had grown in the inclosure.

On August 12, 1916, it was noted that an abundance of wild grasses was coming in so that the *H. hoopesii* at this time was more or less obscured. Outside the area very little grass was seen.

September 6, 1917, practically two years after the plot was fenced off, another examination was made. To superficial observation the *H. hoopesii* seemed nearly as abundant within the inclosure as outside, but there was a good growth of wheat grass with a good deal of yarrow and many dandelions. Actual count of the number of *H. hoopesii* plants on measured typical areas inside and outside

showed that the outside range had about one-third more *H. hoopesii* plants than the area inside. This would indicate that at this time there was an actual reduction in the abundance of the *H. hoopesii*.

July 25, 1918, the patch was visited and it was found that sheep had broken in on the upper part of the inclosure and had grazed it considerably, eating especially the dandelions. The *H. hoopesii* of this season was very abundant and thrifty from the fact that the season was wet and favored the growth of the plant. It was very evident, however, that the *H. hoopesii* was much more abundant outside the inclosure than within. The area had been somewhat washed by the rains and the grass was not so abundant as would have been expected.

September 9, 1918, a careful examination of the patch was made. By counting the plants on measured typical areas, it appeared that the *H. hoopesii* was nearly twice as abundant outside the inclosure as it was inside. The exact proportion was five to three. Inasmuch as the area outside had been badly trampled and many plants destroyed, it is probable that the difference between the two areas was really greater than that established by the count, for all the plants on a given area of the inclosure would be recognized, while many of those on the outside would have been destroyed by grazing animals. The difference in vegetation between the areas within and without the fence was very marked, and stockmen who had been observing the experiment considered it very good evidence of the beneficial effect produced upon the range by giving it an opportunity to recover.

July 29, 1919, an examination showed that the *H. hoopesii* was still abundant, but, as in the preceding year, was in much smaller numbers than outside.

August 5, 1919, a detailed examination was made. The *H. hoopesii* was matured and on account of the dry season was very nearly in the same condition that it was in September of the preceding year.

Cattle had broken into the inclosure and had grazed upon the grass, apparently having, to a large extent, eaten the seed stems of the grasses. The grass was not quite so thick as early in the season, but this appearance may have been due, in part at least, to the accidental grazing. Again a count was made of the relative number of the *H. hoopesii* plants inside and outside of the inclosure, and it was found that the average was in the ratio of $11\frac{4}{5}$ to 19.

During the summer of 1920 there was an abundance of rain in the mountains, with a consequent vigorous growth of all forms of vegetation. When the patch was examined August 23 it was well covered, the wheat grass which grew all over it being especially marked. There was a considerable quantity of *Gymnolomia multiflora*, which being in blossom at the time, gave the patch a general yellow color when seen from a distance. The other plants present were dande-

lions, yarrow, a few plants of *Agastache* and a bunch of *Rudbeckia occidentalis*. The wheat grass stood between 2 and 3 feet high.

Actual count of *H. hoopesii* plants on measured areas, as in preceding years, showed an average of 14 plants inside to 22 outside.

In summing up the results of these experiments to date, the following statements may be made:

1. The sowing of grass seed was a failure, for all the grasses which came in were from reseeding of the natural grasses of the range.

2. The relative number of *H. hoopesii* plants on a given area had been reduced about one-half as the result of the prevention of grazing.

3. The *H. hoopesii* still remained in considerable abundance and was growing with vigor, and it is by no means clear that this method would accomplish anything more than a reduction of the *H. hoopesii* plants with an opportunity for the growth of grasses and other palatable forage.

4. While, without doubt, the prevention of grazing will do much toward the restoration of the range, in localities where *H. hoopesii* has taken possession, it will take a long time for it to be overcome by other plants. It is a very thrifty plant, propagating both by seeds and vegetatively; so far as known, it has no insect enemies and is likely to hold its own in competition with others. The probabilities of real restoration of the range, in any brief period, are not good. While the resting will benefit a range, it probably would take many years to make anything like a complete restoration.

This experiment will be continued for a further period of years in order to determine as nearly as may be what length of time may be necessary to restore the range to a reasonably good condition.

Prevention of Losses.

The ways by which losses of livestock by poisonous plants may be prevented were discussed in Farmers' Bulletin 720, and, in recapitulating the facts about *H. hoopesii* it may be well to follow, in general, the classification of that bulletin.

Medicinal remedies.—As stated in Bulletin 720, medicinal remedies in most cases of plant poisoning are of minor importance. It has been shown in the case of *H. hoopesii* that the effects of the plant are of such a character that little or no help can be expected from remedies.

Eradication.—This is discussed in detail on pages 39–43, where it is shown that eradication is practically impossible.

Use of range when plants are least poisonous.—Some plants are especially dangerous at certain seasons; *H. hoopesii* is dangerous during the whole season, so that nothing can be gained by confining the grazing to a part of the season.

Allotment of range to animals not affected by H. hoopesii.—It has been shown that cattle are seldom affected by *H. hoopesii* and horses rarely if ever. A partial solution of the difficulty may be made in some cases by allotting sneezeweed ranges to horses or cattle rather than to sheep.

Management of range to secure abundance of forage.—*H. hoopesii* is not eaten because of its attractiveness to grazing animals, but is taken after the supply of other forage plants has been exhausted. On ranges where *H. hoopesii* is abundant, but accompanied by a sufficient supply of other plants, sneezeweed poisoning seldom or never occurs. It is on overgrazed ranges, when little is left but *H. hoopesii*, that the sheep are injured. Such ranges, because of the thriftiness of the plant, grow rapidly worse. It is obvious that an attempt should be made by proper management to restore the range. Theoretically this can be done by so restricting grazing as to permit an abundant growth of desirable range plants and natural reseeding. Unfortunately, as shown on pages 41–43, this is a long and somewhat discouraging process. Yet it seems clear that it is the only way by which the ranges can be made safe. Experience has shown that little can be expected from artificial reseeding. The practical question of so reducing allotments as to permit a range to become restored and remain in good condition is a difficult one to handle, but it does not appear that there is any other way of handling the problem successfully. This means that it is desirable that a range should never be stocked to its full capacity, but that a generous margin of safety should be left. It is appreciated that an ideal management of the range might work hardship on existing permittees, and that the handling of the problem demands not only trained ability and experience to recognize the needs of a particular range, but a high order of tact to bring about desirable changes.

PRACTICAL SUGGESTIONS FOR STOCKMEN ON THE RANGE.

From the standpoint of the owner handling sheep on *H. hoopesii* ranges the question of greatest importance is what practical methods he may use to eliminate or reduce his losses. His interest is in the deductions which may be made from the results of an investigation. It must be recognized that there are some things that man can not change, and that a thorough investigation of a subject may sometimes simply show that under a given set of conditions nothing can be done in the way of relief. It is a decided advantage, however, in such cases to know positively the facts and the conditions controlling the poisoning, so that one can combat the trouble intelligently and not waste his energies in attempting to do impossible things.

By management of the flocks so as to avoid poisoning while on the range very much may be accomplished. Herders should be taught

to recognize the plant and to avoid any extended grazing upon it. It must be remembered that *H. hoopesii* does not ordinarily produce acute cases, but is a cumulative poison with permanent effects. If the herder waits until his flock begins to show symptoms of sickness before removing them from grazing on the plant, he has waited too long. His flock is more or less permanently injured, and recovery after removal to another range will be only partial. It is essential that he should anticipate the trouble. It is not true, of course, that sheep can not be grazed at all where *H. hoopesii* is present, but if the range is so overgrazed that other forage is scarce and the *H. hoopesii* is abundant, the sheep will eat this plant. When the herder perceives that this condition exists, the animals should be moved *before cases of sickness occur*. It is recognized that on some ranges change of location may be difficult, but whether difficult or not it must be done if the flocks are to be preserved from loss. The continued grazing of flocks on *H. hoopesii* is a dangerous custom, and may reasonably be expected to have disastrous results. It should be remembered, too, that these results do not consist simply in immediate losses, but that such flocks are permanently injured and weakened, and lessened in value for succeeding years.

Especial care should be used in trailing sheep from one range to another. Where definite trails are laid out and many sheep pass over them, overgrazing results, and *H. hoopesii* may be practically the only remaining plant. Such trails should be avoided whenever possible, and when they must be used, care should be taken that the animals are well fed before entering them. If they pass through them when hungry, they naturally eat what they can get, and hungry animals on a trail eat with especial eagerness.

SUMMARY.

1. The western sneezeweed, *Helenium* (*Dugaldia*) *hoopesii*, has become very abundant on some of the more elevated and overgrazed stock ranges of the West, especially in Utah.

2. The plant has been proved to be the cause of the disease of sheep known as the "spewing sickness" and has also been shown to be poisonous to cattle.

3. The symptoms produced by the plant, the pathology, and the toxic dosage have been worked out in detail, and it has been shown that a permanent, injurious effect may be produced upon the animals eating any considerable quantity of it.

4. The study of the habits of the plant and experimental work on methods of control have shown that little can be accomplished by attempts at extermination, and that restoration of the range by growth of other plants is an exceedingly slow process.

5. The poisonous principle of *Helenium hoopesii* is an easily decomposed glucosid to which the name "*dugaldin*" has been given. This is a white, amorphous solid, soluble in alcohol, less soluble in water and chloroform. With tannic acid it forms a sparingly soluble compound which is only slightly poisonous.

6. There has been found no medicinal remedy which can be used effectively in treating poisoned animals.

7. From the practical standpoint of the man handling livestock on a sneezeweed range, it is important that the herders should know the plant and appreciate the serious results from grazing upon it. Then it may be possible by proper handling of herds to prevent most of the losses.

LITERATURE CITED.

Barnes, Will C. 1913. Western grazing grounds and forest ranges.

Beath, O. A. 1919. Proceedings of Annual Meeting of the Society for Promotion of Agricultural Research, pp. 39–47.

Glover, Geo. H., and Robbins, W. W. 1915. Colorado plants injurious to live stock. Bul. 211, Agr. Exp. Sta., Colo. Agr. Coll.

Hall, H. M., and Yates, H. S. 1915. Stock-poisoning plants of California. Bul. 249, Univ. Cal. Publications.

Koch, F. J. 1874. Helenium autumnale. Am. Jour. Pharm. Vol. 46, p. 221–227.

Lamson, P. L. 1913. The pharmacological action of helenin. J. Pharmacol. Exp. Ther. Vol. 4, p. 471.

———. 1915. Note concerning helenin. J. Pharmacol. Exp. Ther. Vol. 6, p. 413.

Marsh, C. Dwight. 1916. Prevention of losses of live stock from plant poisoning. Farmers' Bul. 720, Bureau of Animal Industry, U. S. Dept. Agriculture.

———. 1916. The cause of the "Spewing Sickness" of sheep. Circ. A–9, Bureau of Animal Industry, U. S. Dept. Agriculture.

———. 1918. Stock-poisoning plants of the range. Bul. 575, U. S. Dept. Agriculture.

Pammel, L. H. 1910. Manual of poisonous plants. Part I.

———. 1911. Manual of poisonous plants. Part II.

———. 1917. Young sneezeweed poisonous. In Amer. Jour. Vet. Med. V. 12, pp. 461–462.

Reeb, E. 1910. Helenium autumnale and its active principle. J. d. Pharm. von Elsass-Lothringen. Vol. 37, p. 137, 149–153.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 948

Joint Contribution from the Bureau of Markets, GEORGE LIVINGSTON, Chief, and the Bureau of Chemistry, CARL L. ALSBERG, Chief

Washington, D. C. ▼ September 10, 1921

COMPOSITION OF COTTON SEED.[1]

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For crushing purposes cotton seed consists of oil, meal, hulls, linters, and waste matter, the proportion of each varying widely in different sections of production and under different conditions. The composition of seed is influenced by climate, soil, season, fertilizer, and variety, as well as by methods of treatment of the seed before and after the cotton is picked. All of these factors vary so much that seed is of different value not only in widely separated sections and in different years but often in a particular community and at the same time.

This bulletin is issued for the guidance of producers, dealers, and crushers in order that they may know more nearly the content of the product in which they are dealing and be better able to judge the value and consequently the price that can be paid for seed. It sets

[1] Acknowledgment is made of the assistance rendered and the courtesies extended by chemists and oil millers in making available their original records, on which this report is based and which made this investigation possible.

forth data showing as nearly as possible approximate oil and meal yields in each county of the cotton belt. These data are not necessarily conclusive, as the volume of information available for many counties is comparatively small. Moreover, even if complete information as to yields were available, figures could not be laid down which would be absolutely accurate as to subsequent yields. It is believed, however, that the information given herein will be of material assistance to those who apply it with an understanding of general and local market conditions.

SOURCES OF INFORMATION.

Records of analyses of cotton seed made by company and commercial chemists during the five seasons 1914–15 to 1918–19, inclusive, were collected from the original analytical sheets by representatives of the Department of Agriculture. Data regarding 59,964 analyses were thus secured, but records of only 46,029 samples were used in this study, as in order to cover only prime seed records of samples showing marked damage or of samples collected prior to September 1 and subsequent to January 31 are not included. The States of Georgia, South Carolina, and Alabama were the largest contributors of records of analyses, while some other States furnished comparatively few records.

As chemists make and report analyses of clean seed, an arbitrary allowance of 100 pounds of foreign matter and manufacturing loss per ton of seed has been made in presenting these data in order to approach as nearly as possible actual commercial conditions. This is the customary allowance made by chemists and is in line with losses reported by the Bureau of the Census, as shown in Table III, page 6.

SEED PRODUCED AND CRUSHED, BY STATES.

The quantity of seed produced differs materially from the quantity crushed in each State, because a considerable volume is retained on the farms and a considerable movement of seed for crushing from one State to another takes place each year. The quantity of seed crushed in each State during each year and the average for the five years, as compiled from records of the Bureau of the Census, are shown in Table I, page 5. Similar data showing the quantity of seed for crushing produced in each State are shown in Table II, page 5. As an illustration of the difference between the quantity of seed produced and the quantity crushed in a specific State, it is noted that in Tennessee an average of 123,000 tons was produced and an average of 264,000 tons was crushed. In Table III, page 6, are given the average total quantity of products and the average manufacturing loss per ton of seed, and in Table IV, page 6, the

average yields of oil and meal, as compiled from records of the Bureau of the Census.

YIELDS OF OIL AND MEAL, BY STATES AND COUNTIES.

The yields of oil and meal in each State and in the United States during each year, also the five-year average yields, as compiled from the records of analyses, are shown in Table V, page 7. Yields by States shown by these analyses are very close to actual yields, as reported by oil millers to the Bureau of the Census. It should be remembered that information based on analyses applies to seed produced within each State, whereas the information based on actual yields applies to seed crushed within each State, which amounts have been shown to vary considerably. Also, information given in Table V is based on meal with a theoretical ammonia content of 8 per cent in Texas and Oklahoma and 7 per cent in all other States, whereas that reported in Table IV is based on the actual meal produced at the mills, regardless of composition. This close agreement between the data from the two different sources is interesting in that it indicates the reliability of the analyses and the data presented in Tables V, page 7, to VIII, page 209, inclusive. However, as previously pointed out, the yields for individual counties as presented in Table VI, page 8, in some instances probably are not representative, on account of the small number of records, or other conditions beyond control of the investigation. The maps of the different States on pages 211 to 221 show the average yields of oil per ton of seed by counties in ranges of 15 pounds.

YIELDS OF OIL AND MEAL, BY MONTHS.

Qualities of seed vary as the season advances. Early seed usually has a greater moisture and smaller oil content, and late seed is usually affected adversely by weather conditions. Table VII, page 202, shows the monthly variation of oil and meal yields for each of the five years and an average for the period for the United States and for individual States. As only the five months, September to January, inclusive, are shown, the variations do not appear so great as they would were the entire season represented.

VARIATION OF YIELDS OF OIL AND MEAL ON SAME MARKET.

In Table VIII, page 209, data are presented which show a few selected examples of variations in oil and meal yields in the same market on the same day. It will be noted that with seed grown under conditions which may appear similar to the seller and buyer, a considerable difference in intrinsic value sometimes exists. A determination of such differences is, of course, impossible in most instances without a chemical analysis of the seed at the time of sale. Under

present conditions such a course would not be practical, but analyses of carloads of uniform lots of seed would be of material assistance.

FOREIGN MATTER.

Large quantities of useless foreign matter which cost many thousands of dollars and require the use of many freight cars are sold and transported with cotton seed annually. A high content of foreign matter generally causes damage to seed, resulting in a poorer quality and smaller quantity of products. Oil-mill men claim that if the cost for the purchase, handling, and transportation of foreign matter were eliminated money thus saved would go to the producers, as the oil mills could pay higher prices for clean seed without increasing the prices of the manufactured products.

In Plate I is shown a pile of foreign matter removed from one carload of unusually dirty seed. The figures regarding this car of seed were as follows:

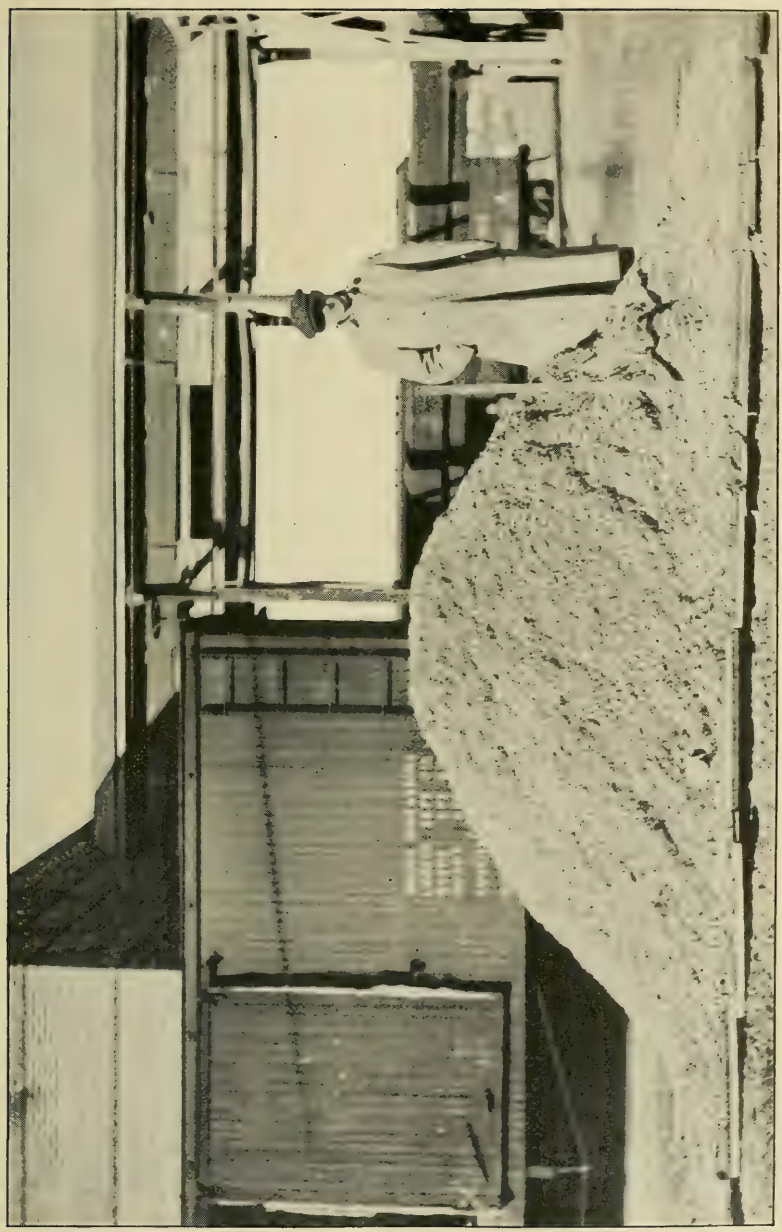
Weight of seed and foreign matter	pounds	31,200
Weight of foreign matter	do	3,500
Net weight of seed	do	27,700

Value net weight of seed at $55 per ton	$761.75
Foreign matter at $55 per ton	96.25
Freight on shipment at $1.50 per ton	23.40
Freight paid on foreign matter	2.62

The oil mill that bought this car of seed cleaned out the foreign matter and paid the shipper only for the net weight of the clean seed. The freight on the trash, however, as well as the expense and trouble of cleaning the seed, was incurred by the mill. A large portion of foreign matter could be eliminated easily if all gins were properly equipped and operated and if cotton seed were sold with reference to cleanness in such a way that clean seed would bring proportionately more than dirty seed.

IMPORTANCE OF ANALYZING COTTON SEED.

A careful study of the figures here presented, together with a study of present-day conditions, will show that if the composition of commercial lots of cotton seed as shown by analyses were known to a greater extent, it would be better for both buyer and seller, and probably the quality of seed would improve greatly. During the five years covered by these records approximately 60,000 analyses were made to determine the quality of seed for purchase or to determine the quality of seed in a particular section or community. In addition to analyses for these purposes, many analyses were made to check the yields at the oil mills. It doubtless will be a distinct forward step when all mills have their seed analyzed and keep close watch of actual yields so that any mechanical or other defect that



FOREIGN MATTER CLEANED FROM ONE CAR OF COTTON SEED.

reduces yields can be immediately discovered and remedied. Analyses also could be of more use to all concerned in determining the value of seed for selling and purchasing, and it is believed that all producers would be well paid for having a sample of each car of uniform seed analyzed so that it might be sold on a basis of actual value.

DAMAGED SEED.

In the collection of these data it was apparent that many lots of seed came to market in a badly damaged condition. This source of loss, which is largely preventable by proper care before and after ginning, is an economic loss for three reasons: First, the oil from damaged seed is of lower value, having a higher refining loss and producing a lower grade of refined oil; second, the meal from damaged seed often is not fit for feeding purposes and can be used only for fertilizer; third, damaged seed in the warehouses in many instances causes seed to heat which otherwise would remain sound. All possible efforts should be taken to prevent damage of seed.

TABLE I.—*Cotton seed crushed in different States, by years.*[1]

State.	5-year average.	1918–19.	1917–18.	1916–17.	1915–16.	1914–15.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
United States	4,638,000	4,479,000	4,252,000	4,479,000	4,202,000	5,780,000
Alabama	291,000	249,000	180,000	198,000	328,000	502,000
Arkansas	309,000	294,000	300,000	368,000	269,000	314,000
Georgia	843,000	841,000	764,000	767,000	791,000	1,054,000
Louisiana	177,000	195,000	201,000	174,000	138,000	176,000
Mississippi	438,000	471,000	426,000	388,000	376,000	528,000
North Carolina	320,000	389,000	262,000	264,000	298,000	388,000
Oklahoma	295,000	221,000	305,000	307,000	229,000	411,000
South Carolina	362,000	421,000	338,000	261,000	328,000	461,000
Tennessee	264,000	292,000	235,000	291,000	226,000	278,000
Texas	1,213,000	955,000	1,121,000	1,350,000	1,123,000	1,515,000
All others	126,000	150,000	119,000	112,000	95,000	154,000

[1] Compiled from Bureau of the Census Bulletin 140.

TABLE II.—*Quantity of crushing seed produced.*[1]

State.	5-year average.	1918–19.	1917–18.	1916–17.	1915–16.	1914–15.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
United States	4,638,000	4,479,000	4,252,000	4,479,000	4,202,000	5,780 000
Alabama	342,000	296,000	196,000	211,000	382,000	624,000
Arizona	13,000	22,000	4,000	----------	----------	----------
Arkansas	368,000	367,000	366,000	443,000	307,000	364,000
California	18,000	27,000	21,000	18,000	8,000	17,000
Florida	17,000	9,000	13,000	18,000	17,000	29,000
Georgia	779,000	788,000	710,000	712,000	719,000	971,000
Louisiana	186,000	219,000	242,000	175,000	130,000	162,000
Mississippi	382,000	457,000	340,000	318,000	357,000	445,000
Missouri	22,000	22,000	21,000	22,000	17,000	29,000
North Carolina	284,000	336,000	234,000	255,000	265,000	335,000
Oklahoma	317,000	215,000	361,000	323,000	240,000	451,000
South Carolina	476,000	582,000	463,000	363,000	424,000	549,000
Tennessee	123,000	121,000	89,000	152,000	113,000	139,000
Texas	1,298,000	1,003,000	1,178,000	1,456,000	1,210,000	1,647,000
Virginia	9,000	9,000	9,000	9,000	8,000	12,000
All others	4,000	4,000	4,000	4,000	4,000	6,000

[1] Compiled from data published in Bureau of the Census Bulletin 140.

TABLE III.—*Total products yielded and manufacturing loss per ton of seed.*[1]

State.	3-year average.		1918–19.		1917–18.		1916–17.	
	Yield.	Loss.	Yield.	Loss.	Yield.	Loss.	Yield.	Loss.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
United States	1,882	118	1,877	123	1,881	119	1,889	111
Alabama	1,876	124	1,882	118	1,865	135	1,879	121
Arkansas	1,871	129	1,859	141	1,878	122	1,874	126
Georgia	1,881	119	1,886	114	1,874	126	1,883	117
Louisiana	1,866	134	1,857	143	1,854	146	1,889	111
Mississippi	1,890	110	1,884	116	1,892	108	1,896	104
North Carolina	1,860	140	1,870	130	1,845	155	1,861	139
Oklahoma	1,886	114	1,867	133	1,883	117	1,902	98
South Carolina	1,861	139	1,860	140	1,853	147	1,872	128
Tennessee	1,879	120	1,855	145	1,910	90	1,882	118
Texas	1,895	105	1,885	115	1,896	104	1,901	99
All others	1,913	87	1,917	83	1,920	80	1,901	99

[1] Compiled from Bureau of the Census Bulletin 140.

TABLE IV.—*Oil and meal yields per ton of seed.*[1]

State.	3-year average.		1918–19.		1917–18.		1916–17.	
	Oil.	Meal.	Oil.	Meal.	Oil.	Meal.	Oil.	Meal.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
United States	306	978	296	969	309	972	314	993
Alabama	313	971	300	972	313	933	329	1,004
Arkansas	306	982	289	947	320	976	309	1,014
Georgia	321	963	310	947	320	958	335	984
Louisiana	307	1,047	295	1,024	311	1,043	316	1,079
Mississippi	322	1,012	305	1,003	330	1,007	333	1,028
North Carolina	321	956	319	958	312	943	332	966
Oklahoma	284	1,001	267	982	289	997	292	1,020
South Carolina	321	959	312	959	319	954	337	967
Tennessee	312	956	292	957	326	930	320	975
Texas	284	975	272	974	285	971	292	979
All others	305	995	298	983	308	1,011	312	995

[1] Compiled from Bureau of the Census Bulletin 140.

NOTE.—Linters and hulls are not accounted for in this table.

TABLE V.—*Yields of oil and meal, by States, as compiled from analyses.*

State.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
United States	46,029	310	985	13,997	297	1,022	8,780	316	967	6,576	317	957	7,895	316	980	8,781	312	978
Alabama	5,259	321	968	1,465	306	1,019	553	328	945	353	335	921	1,385	317	974	1,503	321	967
Arkansas	3,987	307	1,003	1,668	289	1,063	1,214	319	972	417	309	1,028	500	315	981	188	305	1,028
Florida	352	327	1,024	80	319	1,078	145	334	1,008	14	335	957	72	317	1,024	41	334	976
Georgia	14,083	321	948	4,194	307	977	2,359	317	945	2,572	332	900	2,343	323	969	2,615	328	932
Louisiana	2,104	310	1,041	515	304	1,093	605	312	1,063	550	315	1,005	293	312	1,009	141	310	1,015
Mississippi	2,351	311	1,013	1,439	302	1,045	370	317	982	185	321	958	188	312	990	169	316	995
Missouri	338	295	1,005	151	287	989	19	338	940	15	300	970	146	315	999	7	300	1,005
North Carolina	4,065	328	932	1,454	317	977	777	318	901	578	338	899	575	341	955	681	331	949
Oklahoma	906	286	979	190	258	1,020	207	289	1,001	190	282	985	136	309	939	183	299	991
South Carolina	9,277	327	941	1,762	306	979	1,794	321	938	1,029	333	911	1,737	336	961	2,955	337	922
Tennessee	1,323	308	985	623	294	1,040	255	318	916	192	319	957	185	312	987	68	291	1,025
Texas	1,984	279	982	456	273	983	482	277	996	481	289	991	335	282	969	230	273	936

NOTE.—Meal in Texas and Oklahoma is based on a theoretical ammonia content of 8 per cent and in other States 7 per cent.

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses.*

ALABAMA.

BY COUNTIES.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	5,259	321	968	1,465	306	1,019	553	328	945	353	335	921	1,385	317	974	1,503	321	967
Autauga	123	325	956	31	319	1,012	2	342	944	3	346	898	36	303	964	51	317	964
Baldwin	2	314	1,066	2	314	1,066	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Barbour	161	328	946	20	311	1,018	1	347	925	9	346	908	84	312	964	47	322	915
Bibb	11	326	954	.....	.....	.....	2	314	944	1	334	975	4	311	958	4	344	940
Blount	18	325	946	6	292	1,004	3	377	938	1	354	887	4	320	962	4	322	939
Bullock	296	320	959	30	307	1,006	14	334	929	11	325	919	86	316	985	155	316	956
Butler	77	314	975	22	296	1,051	9	320	929	4	331	928	24	316	994	18	307	972
Calhoun	54	324	963	21	310	999	2	336	1,008	21	333	899	2	326	952	8	317	958
Chambers	84	315	930	18	293	954	8	317	904	32	327	885	13	323	950	13	316	957
Cherokee	46	318	960	35	312	1,014	3	333	952	1	329	890	4	314	946	3	304	999
Chilton	97	320	942	21	309	1,011	3	336	911	2	325	884	26	312	964	45	320	939
Choctaw	1	352	988	.....	.....	.....	.....	.....	.....	1	352	988	.....	.....	.....	.....	.....	.....
Clarke	20	322	990	11	313	1,015	1	309	979	2	339	999	5	327	1,027	1	323	928
Clay	9	305	973	1	311	1,064	.....	.....	.....	3	314	906	2	291	952	3	304	968
Cleburne	3	319	972	.....	.....	.....	1	306	956	.....	.....	.....	2	331	987	.....	.....	.....
Coffee	116	318	971	16	300	1,035	13	319	961	2	346	923	26	310	991	59	314	945
Colbert	71	327	947	43	300	1,015	8	336	895	6	351	884	10	331	949	4	316	993
Conecuh	69	328	980	34	308	1,035	3	340	992	7	340	904	11	331	1,018	14	320	953
Coosa	18	331	967	8	325	1,002	.....	.....	.....	2	328	947	5	330	972	3	341	947
Covington	51	316	994	28	297	1,039	5	333	962	.....	.....	.....	6	310	968	12	324	1,007
Crenshaw	117	323	975	33	308	1,041	8	326	966	6	335	921	36	324	962	34	321	984
Cullman	75	324	935	35	305	1,035	5	323	864	5	331	899	9	323	941	31	338	934
Dale	34	321	969	4	326	991	2	311	988	5	313	881	13	312	987	10	324	997
Dallas	317	326	973	19	309	1,001	39	323	968	74	342	930	126	320	980	59	336	984
Dekalb	32	327	984	8	309	1,051	1	332	969	6	352	925	5	317	992	12	326	985

Elmore	172	319	957	31	307	1,022	17	320	948	3	349	885	55	311	962	66	310	968
Escambia	138	317	1,007	45	304	1,045	55	316	999	3	335	1,003	23	309	1,020	12	323	972
Etowah	18	316	948	6	312	1,034	.....	.....	.....	2	338	877	7	324	969	3	291	912
Fayette	8	311	956	2	295	1,007	.....	.....	.....	1	328	922	.....	.....	.....	5	310	940
Franklin	62	323	965	32	302	1,045	3	335	948	5	333	917	10	326	964	12	319	953
Geneva	73	309	1,000	28	297	1,054	7	296	957	2	332	953	16	307	1,033	20	313	1,004
Greene	8	335	969	.....	.....	.....	.....	.....	.....	2	328	938	2	337	975	4	341	995
Hale	45	326	977	5	317	1,043	7	327	959	3	329	942	19	315	986	11	345	957
Henry	47	321	1,008	14	309	1,018	5	325	995	7	333	947	14	315	1,056	7	324	1,022
Houston	124	308	1,007	35	296	1,069	9	314	1,007	18	321	931	42	308	1,046	20	301	982
Jackson	24	320	955	13	310	998	1	336	884	1	300	956	5	308	945	4	345	992
Jefferson	17	321	982	6	299	1,026	.....	.....	.....	1	342	928	5	311	974	5	333	998
Lamar	11	318	974	3	321	978	.....	.....	.....	1	319	941	2	311	996	5	320	982
Lauderdale	40	309	956	25	296	1,025	4	329	903	.....	.....	.....	11	302	941	.....	.....	.....
Lawrence	86	310	972	56	305	1,004	.....	.....	.....	.....	.....	.....	24	315	931	6	310	981
Lee	101	328	954	30	320	980	5	330	961	8	344	915	20	327	943	38	317	970
Limestone	138	317	958	59	302	1,021	13	312	877	2	334	930	55	320	966	9	319	994
Lowndes	187	317	972	21	317	1,021	10	313	953	2	329	926	51	317	986	103	307	975
Macon	140	324	957	28	308	1,021	15	319	925	2	359	868	62	320	987	33	315	984
Madison	67	320	967	34	301	1,025	15	334	917	.....	.....	.....	18	326	960	.....	.....	.....
Marengo	172	321	993	70	303	1,041	55	323	974	3	347	972	27	307	1,004	17	323	973
Marion	17	329	965	1	297	1,054	2	331	902	1	356	928	4	342	962	9	321	977
Marshall	34	318	945	11	298	1,025	1	325	852	11	320	931	3	316	972	8	329	943
Mobile	9	307	961	2	292	1,015	1	311	940	.....	.....	.....	4	310	968	2	315	921
Monroe	131	320	968	25	300	1,016	82	322	992	1	339	921	8	317	957	15	321	955
Montgomery	485	319	968	98	304	1,006	55	322	966	3	339	890	110	315	1,006	219	315	971
Morgan	252	328	962	182	298	1,007	2	354	975	7	347	920	35	318	949	26	322	958
Perry	23	317	962	2	309	982	5	335	988	1	316	934	6	306	959	9	321	947
Pickins	3	317	1,009	2	310	1,023	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	324	994
Pike	149	321	946	14	311	1,026	3	328	941	6	337	880	69	314	932	57	315	952
Randolph	9	329	951	2	323	988	.....	.....	.....	4	348	880	3	306	984	.....	.....	.....
Russell	206	321	956	40	304	1,007	11	335	924	11	341	883	52	313	1,000	92	313	965
Saint Clare	26	318	964	2	281	1,051	5	339	910	3	322	912	5	323	977	11	327	968
Shelby	40	323	957	3	309	989	3	336	922	1	336	947	9	312	975	24	322	953
Sumter	14	325	961	1	314	.....	.....	.....	.....	3	333	952	8	321	954	2	331	977
Talladega	82	318	954	28	305	1,008	10	321	944	13	329	876	15	310	954	16	325	987
Tallapoosa	83	326	935	31	313	945	1	336	937	10	345	906	22	321	950	19	315	939
Tuscaloosa	12	324	954	.....	.....	.....	3	332	963	1	319	899	5	310	991	3	336	962
Walker	27	317	964	4	296	1,076	2	317	878	4	330	942	4	325	951	13	315	975
Washington	2	335	1,009	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	335	1,009	.....	.....	.....
Wilcox	62	320	992	23	306	1,039	11	322	993	2	350	950	13	293	965	13	328	1,013
Winston	13	322	953	5	291	975	2	353	964	1	322	921	1	334	940	4	212	965

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Autauga:																		
September				14	315	1,007				2	360	940	7	306	934	4	317	972
October				10	306	1,026	2	342	944	1	331	855	13	306	950	14	317	959
November				1	327	979							8	296	998	9	320	969
December				2	328	1,029							8	303	975	12	323	959
January				4	319	1,017										12	310	963
Average	123	325	956	31	319	1,012	2	342	944	3	346	898	36	303	964	51	317	964
Baldwin:																		
November				1	309	1,089												
December				1	319	1,042												
Average	2	314	1,066	2	314	1,066												
Barbour:																		
September				15	311	979	1	347	925	1	353	899	22	315	956	10	330	944
October				2	305	1,035				3	344	925	40	309	921	13	315	906
November				2	315	998				5	341	899	8	316	982	4	311	903
December				1	314	1,058							14	309	998	17	323	915
January																3	332	909
Average	161	328	946	20	311	1,018	1	347	925	9	346	908	84	312	964	47	322	915
Bibb:																		
September										1	334	975						
October													1	316	953			
November							2	314	944							2	321	906
December													2	312	937	1	355	918
January													1	304	985	1	355	997
Average	11	326	954				2	314	944	1	334	975	4	311	958	4	344	940

Blount:																		
September				1	285	1,001	1	346	1,064				1	322	934			
October							1	340	909	1	354	887						
November				2	296	982	1	325	842				2	329	975	2	332	956
December				1	293	991												
January				2	295	1,042							1	309	978	2	312	922
Average	18	325	946	6	292	1,004	3	337	938	1	354	887	4	320	962	4	322	939
Bullock:																		
September				20	308	1,001	8	341	947	6	336	899	27	327	972	25	318	972
October				3	306	1,013	3	338	918	3	341	893	34	315	956	31	313	950
November				5	293	1,004	3	322	922	1	346	944	11	310	994	31	319	978
December				2	320	1,007				1	276	940	14	313	1,017	36	318	928
January																32	313	950
Average	296	320	959	30	307	1,006	14	334	929	11	325	919	86	316	985	155	316	956
Butler:																		
September				10	303	1,035	4	330	963	2	337	909	5	331	985	1	303	950
October				5	293	1,070	4	314	979	2	325	947	8	324	985	9	308	960
November				2	290	1,035	1	316	846				8	314	997	4	311	950
December				5	299	1,064							3	293	1,010	3	304	1,001
January																1	311	997
Average	77	314	975	22	296	1,051	9	320	929	4	331	928	24	316	994	18	307	972
Calhoun:																		
September				5	305	998				2	338	861				4	333	944
October				11	307	1,004	1	346	941	2	343	915	1	329	950	3	318	925
November				2	319	982	1	325	1,074				1	323	953			
December				2	303	963				17	317	921						
January				1	314	1,048										1	300	1,004
Average	54	324	963	21	310	999	2	336	1,008	21	333	899	2	326	952	8	317	958
Chambers:																		
September				1	271	956	3	308	902	3	329	849	8	309	899			
October				5	315	915	5	325	906	9	334	890	4	333	915	2	328	956
November				2	287	994				9	330	902				3	317	985
December				6	296	963				10	318	903				3	317	947
January				4	296	940				1	325	880	1	326	1,035	5	302	941
Average	84	315	930	18	293	954	8	317	904	32	327	885	13	323	950	13	316	957
Cherokee:																		
September				2	307	969							1	319	998			
October				23	308	1,010	1	330	998				1	301	890			
November				6	316	997	2	335	906				2	322	950	1	293	1,048
December				3	317	1,039										2	314	950
January				1	314	1,055				1	329	890						
Average	46	318	960	35	312	1,014	3	333	952	1	329	890	4	314	946	3	304	999

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Chilton:																		
September				12	309	994	1	331	903	2	325	884	10	321	947	15	326	941
October				5	304	1,017	2	341	918				5	305	966	13	323	956
November				1	301	1,029							4	308	940	8	321	944
December				2	314	1,036							5	319	985	4	324	931
January				1	318	979							2	309	982	5	304	922
Average	97	320	942	21	309	1,011	3	336	911	2	325	884	26	312	964	45	320	939
Choctaw:																		
September										1	352	988						
Average	1	352	988							1	352	988						
Clarke:																		
September				2	314	988				1	344	1,026	2	323	1,016	1	323	928
October							1	309	979				2	328	1,004			
November				4	310	1,051				1	333	972						
December				5	314	1,007												
January													1	330	1,061			
Average	20	322	990	11	313	1,015	1	309	979	2	339	999	5	327	1,027	1	323	928
Clay:																		
September				1	311	1,064												
October													1	285	921	1	307	991
November										1	319	928						
December										2	308	883	1	297	982			
January																2	301	944
Average	9	305	973	1	311	1,064				3	314	906	2	291	952	3	304	968

Cleburne:																		
November							1	306	956				1	343	980			
December													1	343	994			
Average	3	319	972				1	306	956				2	331	987			
Coffee:																		
September				8	307	1,039	10	320	978	1	376	906	10	317	972	8	323	979
October				3	291	1,035	2	308	972	1	315	940	8	311	960	13	308	934
November				4	301	1,036	1	329	934				5	309	982	12	314	947
December				1	300	1,029							3	304	1,051	11	309	931
January																15	315	934
Average	116	318	971	16	300	1,035	13	319	961	2	346	923	26	310	991	59	314	945
Colbert:																		
September				18	297	1,017	4	349	877	6	351	884	6	328	902	2	315	991
October				8	297	1,010	3	330	921				2	333	953	1	315	1,010
November				6	308	1,016							2	333	991	1	318	979
December				7	304	1,035												
January				4	293	997	1	329	887									
Average	71	327	947	43	300	1,015	8	336	895	6	351	884	10	331	949	4	316	993
Conecuh:																		
September				15	310	1,035	2	327	1,004	5	351	940	3	328	1,004	5	322	972
October				12	300	1,036							5	327	979	3	310	902
November				2	302	1,010	1	352	979				1	352	1,064	2	336	1,013
December				3	313	1,023							1	331	1,004	4	311	925
January				2	313	1,070				2	328	868	1	316	1,039			
Average	69	328	980	34	308	1,035	3	340	992	7	340	904	11	331	1,018	14	320	953
Coosa:																		
September				2	333	1,020				1	325	941	1	346	966	1	331	969
October				1	334	1,010							3	326	925	1	336	868
November				3	311	1,020				1	331	953				1	357	1,004
December				1	317	947							1	319	1,026			
January				1	330	1,013												
Average	18	331	967	8	325	1,002				2	328	947	5	330	972	3	334	1,007
Covington:																		
September				11	295	1,026	3	334	960							7	315	982
October				4	292	1,023	1	342	947				5	299	922	2	300	991
November				4	302	1,042										2	327	979
December				3	295	1,039	1	324	979				1	320	1,013	1	352	1,074
January				6	303	1,064												
Average	51	316	994	28	297	1,039	5	333	962				6	310	968	12	324	1,007

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Crenshaw:																		
September				15	299	1,036	4	331	975	3	351	956	15	314	940	5	318	1,004
October				4	310	1,070	2	323	944	1	332	909	9	318	947	4	321	988
November				6	295	1,048	2	325	979	2	321	899	5	329	975	6	325	991
December				7	306	1,039							7	333	985	10	320	978
January				1	332	1,013										9	319	959
Average	117	323	975	33	308	1,041	8	326	966	6	335	921	36	324	962	34	321	984
Cullman:																		
September				12	282	988	1	325	903	2	348	874				1	353	941
October				13	302	1,016	2	323	906	2	333	899	1	335	959	10	330	925
November				3	314	1,055	1	330	858	1	313	925	8	310	922	4	339	940
December				5	313	1,045	1	312	789							2	338	937
January				2	314	1,073										4	332	928
Average	75	324	935	35	305	1,035	5	323	864	5	331	899	9	323	941	21	338	934
Dale:																		
September				3	328	978				4	330	912	4	326	1,007	1	289	1,007
October				1	323	1,004							3	312	960	2	310	1,001
November							2	331	988	1	296	849	1	315	988	3	346	1,013
December													3	308	997	1	360	953
January													2	298	982	3	315	1,013
Average	34	321	969	4	326	991	2	331	988	5	313	881	13	312	987	10	324	997
Dallas:																		
September				9	307	975	9	325	1,004	28	352	941	39	320	960	22	342	963
October				4	311	1,010	21	323	960	20	348	921	28	320	960	16	343	963
November				3	315	975	9	320	941	20	334	925	28	323	985	12	333	979
December				3	303	1,045				6	333	931	23	323	997	4	330	1,001
January													8	312	998	5	332	1,016
Average	317	326	973	19	309	1,001	39	323	968	74	342	930	126	320	980	59	336	984

Dekalb:																		
September				1	302	1,080	1	332	969	1	363	931						
October				4	311	1,067				4	351	925	1	338	1,029	1	319	1,029
November										1	342	918	3	313	1,004	6	316	979
December				3	314	1,007							1	300	942	4	321	960
January																1	348	972
Average	32	327	984	8	309	1,051	1	332	969	6	352	925	5	317	992	12	326	985
Elmore:																		
September				8	307	1,004	3	315	947	1	342	874	10	317	944	1	296	1,016
October				5	309	1,016	6	325	950	1	365	912	25	304	966	13	313	956
November				9	311	1,017	8	320	947	1	340	868	5	302	950	16	313	956
December				6	300	1,026							12	301	991	24	312	953
January				3	308	1,048							3	332	960	12	314	959
Average	172	319	957	31	307	1,022	17	320	948	3	349	885	55	311	962	66	310	968
Escambia:																		
September				20	306	1,036	21	325	1,020	1	343	1,017	4	328	1,055	2	325	982
October				12	305	1,061	19	316	998				10	311	988	4	322	941
November				4	295	1,032	9	317	985				4	305	1,020	2	335	1,007
December				5	301	1,058	6	307	991	2	327	988	5	291	1,016	4	320	956
January				4	311	1,036												
Average	138	317	1,007	45	304	1,045	55	316	999	3	335	1,003	23	309	1,020	12	323	972
Etowah:																		
September										1	343	890						
October				1	323	1,032				1	333	864	4	329	972			
November				2	300	1,010							3	319	966			
December				2	293	1,039												
January				1	333	1,054										3	291	912
Average	18	316	948	6	312	1,034				2	338	877	7	324	969	3	291	912
Fayette:																		
September				2	295	1,007												
October										1	328	922				3	312	988
November																1	315	925
January																1	303	906
Average	8	311	956	2	295	1,007				1	328	922				5	310	940
Franklin:																		
September				11	306	1,036	1	340	921				6	321	959	2	336	941
October				7	303	1,048	1	333	982	3	353	925	3	340	960	5	315	944
November				2	327	1,105	1	331	941	1	314	928				4	312	988
December				10	296	1,016				1	332	899				1	314	937
January				2	278	1,020							1	317	972			
Average	62	323	965	32	302	1,045	3	335	948	5	333	917	10	326	964	12	319	953

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Geneva:																		
September				2	292	1,045	6	296	963	2	332	953	8	310	1,029	8	316	1,032
October				2	295	1,096	1	295	950				6	301	1,035	7	312	1,016
November				13	290	1,032										2	321	982
December				9	305	1,032							2	310	1,036			
January				2	301	1,064										3	304	985
Average	73	309	1,000	28	297	1,054	7	296	957	2	332	953	16	307	1,033	20	313	1,004
Greene:																		
September													2	337	975	1	351	1,026
October										1	327	934				1	325	969
November										1	329	941						
December																2	347	991
Average	8	335	969							2	328	938	2	337	975	4	341	995
Hale:																		
September				2	336	960				1	333	940	2	303	944	4	352	988
October							4	322	953				9	315	982	4	345	966
November				1	315	1,074	2	332	950	2	324	944	4	307	994	2	331	902
December				2	301	1,096							3	317	1,026	1	353	972
January							1	326	975				1	331	982			
Average	45	326	977	5	317	1,043	7	327	959	3	329	942	19	315	986	11	345	957
Henry:																		
September				5	299	985	4	328	1,010	5	344	915	9	320	1,048	1	319	1,020
October				4	321	994	1	322	979	2	322	978	3	316	1,073			
November				2	308	1,042							2	310	1,048	2	345	1,061
December				1	310	1,055										1	315	979
January				2	305	1,016										3	316	1,029
Average	47	321	1,008	14	309	1,018	5	325	995	7	333	947	14	315	1,056	7	324	1,022

Houston:																		
September				25	296	1,045	9	314	1,007	12	324	912	28	306	998	10	301	1,007
October				4	294	1,074				5	337	940	10	307	1,054	1	307	950
November				2	295	1,045							2	313	1,039			
December				4	300	1,111				1	303	940	1	304	1,102	2	293	1,010
January													1	309	1,036	7	303	959
Average	124	308	1,007	35	296	1,069	9	314	1,007	18	321	931	42	308	1,046	20	301	982
Jackson:																		
September				1	301	988												
October				3	312	1,001							3	328	956	3	352	982
November				3	317	1,020							1	280	896	1	337	1,001
December				5	304	1,055				1	300	956	1	317	982			
January				1	314	925	1	336	884									
Average	24	320	955	13	310	998	1	336	884	1	300	956	5	308	945	4	345	992
Jefferson:																		
September				1	293	1,020				1	842	928				1	326	1,032
October				1	305	1,061										1	325	928
November				1	293	1,026							1	303	966	2	314	997
December				2	302	1,051												
January				1	302	972							4	318	982	1	366	1,036
Average	17	321	982	6	299	1,026				1	342	928	5	311	974	5	333	998
Lamar:																		
September				3	321	978												
October													1	316	963			
November										1	319	941				3	315	985
December													1	305	1,029			
January																2	325	978
Average	11	318	974	3	321	978				1	319	941	2	311	996	5	320	982
Lauderdale:																		
September				3	305	1,039							1	329	915			
October				7	291	1,042	4	329	903									
November				9	303	1,036							8	302	969			
December				6	286	982							2	276	940			
Average	40	309	956	25	296	1,025	4	329	903				11	302	941			
Lawrence:																		
September				8	306	997							6	303	928	2	314	991
October				4	310	991							18	327	934	3	309	953
November				2	306	1,032										1	308	998
December				21	304	997												
January				21	299	1,001												
Average	86	310	972	56	305	1,004							24	315	931	6	310	981

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Lee:																		
September				4	319	972				2	348	896	13	324	921	4	313	979
October				10	323	988	1	343	972	4	335	865	5	334	925	7	311	978
November				6	315	960	3	335	925	1	350	1,007	2	324	982	15	323	972
December				8	315	966				1	344	893				6	314	994
January				2	328	1,013	1	313	985							6	322	925
Average	101	328	954	30	320	980	5	330	961	8	344	915	20	327	943	38	317	970
Limestone:																		
September				8	295	997				1	346	877	4	325	922	3	320	1,007
October				21	304	1,032							40	331	950	3	317	978
November				9	304	1,061	3	315	877				10	315	982	3	319	998
December				12	310	1,010				1	321	982						
January				9	299	1,007	10	308	877				1	307	1,010			
Average	138	317	958	59	302	1,021	13	312	877	2	334	930	55	320	966	9	319	994
Lowndes:																		
September				11	314	1,004	1	324	937	1	344	788	20	316	969	16	303	985
October							5	313	941				15	306	979	30	307	979
November				5	314	1,010	2	325	921	1	313	1,064	8	303	988	31	308	998
December				3	320	1,051	2	288	1,013				7	314	1,013	20	315	972
January				2	318	1,020							1	346	979	6	302	941
Average	187	317	972	21	317	1,021	10	313	953	2	329	926	51	317	986	103	307	975
Macon:																		
September				10	306	1,029	2	315	918	1	364	852	21	336	988	3	319	1,017
October				8	307	1,007	7	316	903	1	353	884	17	318	982	9	318	966
November				5	308	1,032	6	325	953				3	315	953	6	317	972
December				5	309	1,016							19	315	1,017	4	309	982
January													2	317	997	11	314	985
Average	140	324	957	28	308	1,021	15	319	925	2	359	868	62	320	987	33	315	984

Madison:																		
September				7	285	1,010	4	337	912				5	321	969			
October				9	301	1,013							13	330	950			
November				1	314	1,007												
December				14	306	1,054												
January				3	298	1,042	11	330	922									
Average	67	320	967	34	301	1,025	15	334	917				18	326	960			
Marengo:																		
September				35	310	1,023	8	315	979	3	347	972	9	316	991	6	320	972
October				15	303	1,055	14	325	972				1	298	982	4	323	960
November				9	303	1,032	24	327	966				5	315	1,007	4	332	982
December				7	289	1,039	4	333	963				11	302	1,016	2	326	969
January				4	310	1,054	5	314	991				1	304	1,023	1	315	982
Average	172	321	993	70	303	1,041	55	323	974	3	347	972	27	307	1,004	17	323	973
Marion:																		
September							2	331	902				1	332	934			
October										1	356	928	1	348	969	2	311	997
November													2	345	982	6	319	988
December				1	297	1,054										1	334	947
Average	17	329	965	1	297	1,054	2	331	902	1	356	928	4	342	962	9	321	977
Marshall:																		
September				2	282	1,045												
October				2	296	1,061				3	350	915	1	330	982	3	302	934
November				1	306	956	1	325	852	1	317	937				2	351	950
December				5	302	1,032				2	303	890	1	307	979	3	333	944
January				1	302	1,032				5	308	893	1	310	956			
Average	34	318	945	11	298	1,025	1	325	852	11	320	931	3	316	972	8	329	943
Mobile:																		
September				1	288	991							1	314	985			
October							1	311	940				1	316	969			
November													2	299	950	1	334	883
December				1	295	1,039										1	295	959
Average	9	307	961	2	292	1,015	1	311	940				4	310	968	2	315	921
Monroe:																		
September				11	320	1,020	38	325	982				2	310	966	1	299	922
October				5	298	1,029	20	315	978				2	319	921	3	326	944
November				1	293	940	18	322	997	1	339	921	4	323	985	4	324	966
December				5	304	1,061	6	325	1,010							3	334	963
January				3	285	1,032										4	321	979
Average	131	320	968	25	300	1,016	82	322	992	1	339	921	8	317	957	15	321	955

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Montgomery:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				40	308	1,017	33	324	966	1	323	842	44	319	979	61	311	991
October				37	314	1,026	10	321	950	1	348	925	22	313	988	69	311	972
November				13	305	1,013	12	321	982	1	346	903	25	311	1,016	39	324	985
December				5	292	972							15	308	1,039	37	317	959
January				3	300	1,004							4	323	1,010	13	314	950
Average	485	319	968	98	304	1,006	55	322	966	3	339	890	110	315	1,006	219	315	971
Morgan:																		
September				7	291	1,017	2	354	975	5	344	871	6	326	937	15	323	985
October				58	304	1,010				2	349	969	21	323	950	6	314	922
November				45	303	1,013							8	305	960	4	321	966
December				44	298	994												
January				28	295	1,001										1	329	960
Average	252	328	962	182	298	1,007	2	354	975	7	347	920	35	318	949	26	322	958
Perry:																		
September				1	294	1,001	1	358	956				3	314	941	1	310	988
October				1	323	963	3	322	979				2	302	934			
November							1	324	1,029	1	316	934	1	303	1,001	5	329	988
December																3	323	864
Average	23	317	962	2	309	982	5	335	988	1	316	934	6	306	959	9	321	947
Pickens:																		
December				2	310	1,023												
January																1	324	994
Average	3	317	1,009	2	310	1,023										1	324	994

Pike:																		
September				4	308	1,039	1	340	1,042	4	334	883	22	323	925	11	308	991
October				7	314	1,035	1	336	928	1	340	868	14	306	909	5	311	953
November													12	313	950	7	324	931
December				3	312	1,004	1	308	852	1	337	890	21	312	944	21	305	940
January																13	326	947
Average	149	321	946	14	311	1,026	3	328	941	6	337	880	69	314	932	57	315	952
Randolph:																		
September				1	313	997							2	296	999			
October										4	348	880	1	316	969			
December				1	332	979												
Average	9	329	951	2	323	988				4	348	880	3	306	984			
Russell:																		
September				12	300	972	4	324	928	9	351	903	23	321	975	11	315	1,004
October				11	295	1,001	3	343	925	1	334	902	17	322	966	33	317	960
November				8	312	1,020	2	338	928	1	337	845	5	298	1,026	14	321	978
December				7	301	1,020	2	335	915				6	297	1,016	17	302	944
January				2	314	1,023							1	327	1,017	17	314	940
Average	206	321	956	40	304	1,007	11	335	924	11	341	883	52	313	1,000	92	313	965
St. Clair:																		
September				1	276	997							2	324	947	2	327	940
October							1	331	928	2	331	902				3	330	956
November				1	285	1,105	2	347	928				2	305	1,032	4	329	997
December																2	320	979
January							2	340	874	1	312	921	1	339	953			
Average	26	318	964	2	281	1,051	5	339	910	3	322	912	5	323	977	11	327	968
Shelby:																		
September				1	301	979							1	315	994	2	323	985
October				1	308	963	2	333	928	1	335	947	4	324	966	13	309	960
November				1	319	1,026	1	338	915				1	305	947	8	314	963
December													3	303	991	1	343	902
Average	40	323	957	3	309	989	3	335	922	1	335	947	9	312	975	24	322	953
Sumter:																		
September										2	320	915	4	316	956			
October				1	314					1	346	988	2	329	884			
November													2	317	1,023	1	318	944
January																1	344	1,010
Average	14	325	961	1	314					3	333	952	8	321	954	2	331	977

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ALABAMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Talladega:																		
September				13	305	1,048				9	332	871	6	311	978	4	307	991
October				7	302	1,023	3	326	950	4	326	880	7	311	934	4	319	997
November				2	303	988	7	315	937							3	331	997
December				5	300	997							1	310	906	2	333	978
January				1	313	985							1	309	997	3	336	972
Average	82	318	934	28	305	1,008	10	321	944	13	329	876	15	310	954	16	325	987
Tallapoosa:																		
September				5	324	906				1	365	883	9	324	909	3	310	918
October				9	315	947				1	342	922	11	323	988	5	314	937
November				10	323	950				3	343	925				2	318	959
December				6	297	956				3	332	921				4	317	928
January				1	305	966	1	336	937	2	343	880	2	317	953	5	314	953
Average	83	326	935	31	313	945	1	336	937	10	345	906	22	321	950	19	315	939
Tuscaloosa:																		
September							1	348	953	1	319	899	2	313	979			
October													2	308	1,016	1	323	950
November							2	316	972							1	317	940
December													1	309	979	1	367	997
Average	12	324	954				3	332	963	1	319	899	5	310	991	3	336	962
Walker:																		
September				1	294	1,096							1	333	944	1	310	978
October										2	324	937	2	342	950	4	328	997
November							1	327	909	2	335	947				5	305	988
December				3	298	1,055							1	299	959	3	318	937
January							1	307	846									
Average	27	317	964	4	296	1,076	2	317	878	4	330	942	4	325	951	13	315	975

Washington:																		
October													1	339	972			
November													1	331	1,045			
Average	2	335	1,009										2	335	1,009			
Wilcox:																		
September				7	306	1,061	1	321	988	1	356	921	3	294	960	2	324	1,026
October				6	300	1,036	4	325	1,007				6	316	979	4	332	1,026
November				2	310	998	4	325	959				2	276	960	2	320	1,004
December				7	302	1,055	2	317	1,017	1	344	978	2	287	959	5	336	997
January				1	314	1,045												
Average	62	320	992	23	306	1,039	11	322	993	2	350	950	13	293	965	13	328	1,013
Winston:																		
September				1	272	975	1	350	896				1	334	940			
October										1	322	921				1	320	956
November							1	355	1,032							2	314	931
December				4	309	975										1	302	1,007
Average	13	322	953	5	291	975	2	353	964	1	322	921	1	334	940	4	312	965

ARIZONA.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	5	315	1,065							5	315	1,065						
Maricopa	4	310	1,031							4	310	1,031						
Yuma	1	319	1,099							1	319	1,099						

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARIZONA—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Maricopa:																		
September										3	317	1,064						
October										1	302	998						
Average	4	310	1031							4	310	1,031						
Yuma:																		
November										1	319	1,099						
Average	1	319	1099							1	319	1,099						

ARKANSAS.

BY COUNTIES.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	3,989	307	1,005	1,668	289	1,063	1,214	319	972	417	309	1,028	500	315	981	188	305	1,028
Arkansas	15	293	1,021	5	267	1,063	3	320	1,041	2	284	1,058	5	304	920			
Ashley	49	300	1,056	16	281	1,099	29	311	1,031	3	336	1,017				1	272	1,077
Baxter	4	305	988	3	312	1,051	1	298	925									
Benton	8	292	991	6	296	1,058	1	266	950				1	315	966			
Boone	1	336	963				1	336	963									

Bradley	6	312	978	3	274	1,088	1	329	877				2	332	968			
Calhoun	18	304	1,002	8	278	1,064	7	313	961	1	311	1,007	2	315	975			
Carroll	4	350	1,098				2	342	1,047				1	334	1,032	1	374	1,216
Chicot	81	320	1,031	40	295	1,036	24	325	1,018	5	334	1,036	4	324	1,055	8	320	1,034
Clark	50	310	1,015	15	281	1,046	32	308	999	2	319	1,102	1	331	912			
Clay	116	303	967	23	283	1,017	29	316	882	13	302	999	51	311	971			
Cleburne	10	323	985	6	300	1,002	3	339	958	1	329	994						
Cleveland	31	299	1,049	18	283	1,111	11	303	1,010				2	310	1,026			
Columbia	34	306	974	12	284	1,041	3	321	953	2	303	972	15	318	958	2	302	947
Conway	37	306	997	14	285	1,028	11	323	920	1	302	1,093	7	316	925	4	306	1,017
Craighead	78	303	998	50	289	1,023	17	321	940	4	295	1,003	5	308	1,024	2	301	998
Crawford	32	303	1,047	5	293	1,096	20	309	997	7	306							
Crittenden	208	319	972	140	301	1,026	37	335	935	15	325	987	14	316	1,030	2	320	883
Cross	61	298	1,018	37	292	1,050	16	295	922	2	306		3	290	1,019	3	305	1,080
Dallas	23	312	1,032	10	284	1,036	4	320	977	1	317	1,099	4	308	1,022	4	329	1,026
Desha	84	317	1,010	37	300	1,027	35	327	997	6	325	1,036	5	329	947	1	302	1,045
Drew	24	307	1,030	6	292	1,059	15	316	984	1	307	1,080	1	343	883	1	275	1,143
Faulkner	52	309	1,014	10	298	1,071	26	325	946	6	308	1,073	8	329	980	2	285	998
Franklin	24	293	1,041	4	297	1,062	17	315	1,020	2	293					1	265	
Fulton	9	299	983	4	273	1,112	1	321	874				4	302	964			
Garland	7	304	1,055	3	287	1,088	4	320	1,021									
Grant	10	298	1,022	6	305	1,058	3	318	985							1	270	
Greene	105	300	980	17	276		23	316	901	4	300	1,054	61	309	986			
Hempstead	104	314	1,003	47	291	1,060	29	318	993	22	308	985	3	330	926	3	323	1,050
Hot Springs	8	279	1,073	8	279	1,073												
Howard	12	300	1,037	6	290	1,053	4	310	997	2	300	1,061						
Independence	62	302	1,023	27	284	1,049	26	301	966	3	299	1,077	3	307	953	3	320	1,069
Izard	3	318	1,036							2	309					1	326	1,036
Jackson	172	300	1,012	45	286	993	47	322	979	18	307	1,069	53	301	972	9	285	1,045
Jefferson	299	315	1,013	114	298	1,030	72	320	1,001	76	328	998	20	310	1,003	17	319	1,032
Johnson	34	313	991	3	280	1,093	17	322	951	8	304	934	2	320	991	4	337	988
Lafayette	34	301	1,025	20	285	1,070	3	320	985	2	302	1,064	8	323	943	1	275	1,061
Lawrence	141	296	991	54	283	1,035	52	306	932	9	288	989	21	301	946	5	304	1,055
Lee	90	312	1,001	61	299	1,017	19	315	988	3	333	937	5	301	1,001	2	313	1,064
Lincoln	58	313	1,015	13	306	1,044	32	323	994	4	309	1,050	6	316	1,009	3	312	979
Little River	10	305	1,050	8	293	1,072	1	316	1,054				1	306	1,023			
Logan	39	297	1,025	13	290	1,068	17	309	1,012	8	287	985	1	303	1,045			
Lonoke	122	309	1,018	22	300	1,053	37	322	976	30	305	1,043	8	319	1,034	25	297	985
Madison	5	308	1,139	1	291	1,194	4	324	1,084									
Marion	15	314	977	5	298	1,019	10	329	935									
Miller	32	318	1,061	14	299	1,080	14	332	1,059	2	314	1,055				2	328	1,050
Mississippi	377	314	977	213	302	1,023	92	326	933	15	318	953	50	315	1,001	7	311	974
Monroe	85	309	1,000	25	290	1,049	12	319	979	16	315	996	27	306	973	5	314	1,001
Montgomery	7	311	991	2	270	1,118	3	329	979	1	325	953	1	320	915			
Nevada	9	284	1,077	6	280	1,085							2	312	1,001	1	261	1,146

TABLE VI.—*Yields of oil and meal, by counties, as compiled by analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Newton	4	317	1,068	1	292	1,124	2	329	1,036				1	330	1,042			
Ouachita	61	306	1,019	34	269	1,092	7	314	1,036				19	305	998	1	334	950
Perry	51	308	1,000	25	300	1,078	15	318	938	8	299	1,013	2	324	949	1	301	1,020
Phillips	163	310	1,000	60	289	1,043	55	317	995	14	320	1,025	16	317	986	18	307	850
Pike	10	311	1,063	2	288	1,112	4	326	1,059	2	303	1,070	2	326	1,009			
Poinsett	87	305	1,002	59	298	1,037	24	323	952				4	295	1,016			
Polk	13	326	1,004	11	302	1,109	1	331	944	1	346	960						
Pope	77	299	999	17	291	1,076	37	320	929	12	294	1,039	3	323	960	8	269	991
Prairie	16	288	1,041	2	268	1,142	13	320	970				1	276	1,010			
Pulaski	102	308	1,004	43	295	1,022	11	311	969	16	306	1,059	12	317	982	20	311	990
Randolph	69	309	968	31	295	1,042	19	330	870	6	293	984	13	316	976			
St. Francis	126	306	1,009	70	301	1,039	34	312	942	14	298	1,015	5	302	1,005	3	317	1,046
Saline	25	320	977	17	305	1,035	4	318	928	2	325		2	331	968			
Scott	3	283	1,152	3	283	1,152												
Searcy	3	335	927				3	335	927									
Sebastian	64	304	1,035	10	284	1,069	37	317	1,029	7	296	1,063	3	321	959	7	302	1,053
Sevier	6	319	1,003	2	302	1,074	2	338	934	2	317	1,001						
Sharp	10	311	1,024	2	298	1,039	5	324	911	2	303	1,118	1	318	1,026			
Stone	5	289	1,019	1	253	1,112	4	325	926									
Union	18	305	958	7	282	1,051	4	320	925	3	316	922	4	302	934			
Van Buren	1	274	1,130	1	274	1,130												
Washington	5	297	1,071	4	301	1,039	1	293	1,102									
White	26	299	1,050	15	276	1,104	8	291	1,023	1	296	1,121	2	331	950			
Woodruff	74	306	1,040	35	292	1,028	27	320	922	7	312	1,055	1	300	991	4	306	1,025
Yell	69	303	1,022	11	275	1,091	30	321	971	21	303	1,115	2	315	956	5	302	978

By Counties and Months.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Arkansas:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
October				2	259	1,108	2	315	1,055				1	310	887			
November				1	272	1,007	1	324	1,026				4	297	953			
December				2	269	1,074				2	284	1,058						
Average	15	293	1,021	5	267	1,063	3	320	1,041	2	284	1,058	5	304	920			
Ashley:																		
September				9	293	1,080	4	302	998	3	336	1,017				1	272	1,077
October				4	279	1,089	5	313	1,029									
November				1	275	1,162	7	320	1,029									
December				1	277	1,042	7	315	1,067									
January				1	279	1,121	6	305	1,032									
Average	49	300	1,056	16	281	1,099	29	311	1,031	3	336	1,017				1	272	1,077
Baxter:																		
November				3	312	1,051	1	298	925									
Average	4	305	988	3	312	1,051	1	298	925									
Benton:																		
September				1	285	1,045												
October				1	311	1,070							1	315	966			
November							1	266	950									
December				3	291													
Average	8	292	991	6	296	1,058	1	266	950				1	315	966			
Boone:																		
December							1	336	963									
Average	1	336	963				1	336	963									
Bradley:																		
September				1	294	1,146	1	329	877									
October				1	273	1,064							1	323	972			
November													1	341	963			
January				1	256	1,054												
Average	6	312	978	3	274	1,088	1	329	877				2	332	968			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Calhoun:																		
September				3	263	1,070				1	311	1,007						
October				3	255	1,105	6	313	969									
November							1	313	953				2	315	975			
January				2	317	1,016												
Average	18	304	1,002	8	278	1,064	7	313	961	1	311	1,007	2	315	975			
Carroll:																		
September							1	341	985							1	374	1,216
October							1	342	1,108				1	334	1,032			
Average	4	350	1,098				2	342	1,047				1	334	1,032	1	374	1,216
Chicot:																		
September				9	305	1,013	5	309	1,039	4	334	1,023	4	324	1,055	3	307	1,054
October				16	311	1,032	14	324	1,051							1	330	1,067
November				8	295	1,054	1	338	997							3	328	998
December				4	303	1,016	3	324	1,055	1	334	1,048						
January				3	262	1,064	1	329	947							1	313	1,016
Average	81	320	1,031	40	295	1,036	24	325	1,018	5	334	1,036	4	324	1,055	8	320	1,034
Clark:																		
September				7	285	994				2	319	1,102						
October				5	297	1,070	11	316	997				1	331	912			
November							11	313	1,023									
December				1	274	1,023	5	303	1,029									
January				2	267	1,096	5	299	947									
Average	50	310	1,015	15	281	1,046	32	308	999	2	319	1,102	1	331	912			

Clay:																		
October				10	279	1,093	9	332	921	3	296	1,051	14	324	975			
November				5	293	1,017	10	320	896	4	308	1,048	27	321	975			
December				3	285		9	313	855	2	303	966	8	295	988			
January				2	283	941				1	295	921	2	303	944			
Average	116	303	967	23	283	1,017	29	316	882	13	302	999	51	311	971			
Cleburne:																		
September				1	322	1,127				1	329	994						
October				5	277	877	2	325	1,039									
November							1	352	877									
Average	10	323	985	6	300	1,002	3	339	958	1	329	994						
Cleveland:																		
September				9	278	1,099	1	274	1,004				2	310	1,026			
October				3	271	1,099	3	296	979									
November				3	290	1,108	4	324	1,036									
December				3	292	1,137	3	318	1,020									
Average	31	299	1,049	18	283	1,111	11	303	1,010				2	310	1,026			
Columbia:																		
September				4	276	1,020				2	303	972	1	333	963	2	302	947
October				7	296	1,067	2	316	928				7	323	925			
November				1	280	1,036	1	326	978				5	305	956			
December													2	310	988			
Average	34	306	974	12	284	1,041	3	321	953	2	303	972	15	318	958	2	302	947
Conway:																		
September				8	284	1,051	2	324	941	1	302	1,093	4	324	928	3	316	1,016
October				2	309	975	3	334	925				1	300	912			
November							3	322	937				2	323	934	1	295	1,017
December				3	292	1,055	2	308	915									
January				1	253	1,029	1	329	880									
Average	37	306	997	14	285	1,028	11	323	920	1	302	1,093	7	316	925	4	306	1,017
Craighead:																		
September				1	276	1,039	2	311	969	2	300	1,080				2	301	998
October				13	291	1,035	7	321	950	1	291	997	2	301	1,051			
November				20	295	1,032	5	331	902				3	314	997			
December				7	298	1,026	3	319	940	1	293	931						
January				9	286	982												
Average	78	303	998	50	289	1,023	17	321	940	4	295	1,003	5	308	1,024	2	301	998

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Crawford:																		
September				3	274	1,108				5	301							
October				1	311	1,146	8	321	1,010									
November							2	305	1,001	2	310							
December							6	306	1,017									
January				1	295	1,035	4	305	959									
Average	32	303	1,047	5	293	1,096	20	309	997	7	306							
Crittenden:																		
September				38	294	1,048	4	325	925	5	325	1,007	3	319	1,013			
October				41	295	1,039	4	346	978	3	330		3	329	1,092			
November				25	308	1,035	13	333	902	1	338		3	330	1,061	2	320	883
December				20	307	1,026	11	329	941	6	308	966	3	295	988			
January				16	299	982	5	343	931				2	309	997			
Average	208	319	972	140	301	1,026	37	335	935	15	325	987	14	316	1,030	2	320	883
Cross:																		
September				19	295	1,080							1	287	1,054	2	314	1,080
October				10	287	1,067	5	302	1,001				1	303	1,035			
November				4	267	1,039	8	310	928	2	306					1	295	
December				1	318	1,036	2	287	877									
January				3	294	1,026	1	281	880				1	279	969			
Average	61	298	1,018	37	292	1,050	16	295	922	2	306		3	290	1,019	3	305	1,080
Dallas:																		
September				1	284	1,039				1	317	1,099				4	329	1,026
October				3	294	1,004							1	311	1,026			
November				4	284	1,064	2	316	1,001				3	305	1,017			
December				2	273													
January							2	323	953									
Average	23	312	1,032	10	284	1,036	4	320	977	1	317	1,099	4	308	1,022	4	329	1,026

Desha:																		
September				4	285	1,055	3	328	994	5	325	1,017	4	346	918	1	302	1,045
October				10	309	994	12	324	1,020				1	312	975			
November				12	305	1,032	7	328	997									
December				10	308	1,017	6	331	991									
January				3	295	1,039	7	325	982	1	324	1,055						
Average	84	317	1,010	37	300	1,027	35	327	997	6	325	1,036	5	329	947	1	302	1,045
Drew:																		
September				1	313	1,096	3	325	893	1	307	1,080	1	343	883	1	275	1,143
October				3	272	1,127	6	325	1,004									
November							2	331	985									
December				1	284	941	3	318	1,017									
January				1	297	1,073	1	280	1,023									
Average	24	307	1,030	6	292	1,059	15	316	984	1	307	1,080	1	343	883	1	275	1,143
Faulkner:																		
September				4	277	1,055				4	316	1,073	4	321	1,020	1	319	998
October				2	275	1,096	9	329	925				3	324	972			
November				1	307	1,092	10	324	969	1	301		1	342	947			
December				2	314	1,029	7	322	944	1	306							
January				1	315	1,083										1	251	
Average	52	309	1,014	10	298	1,071	26	325	946	6	308	1,073	8	329	980	2	285	998
Franklin:																		
September										1	301							
October				2	298	1,105	4	336	994									
November							4	314	1,077	1	285							
December				1	297	1,058	4	311	975									
January				1	295	1,023	5	298	1,035							1	265	
Average	24	293	1,041	4	297	1,062	17	315	1,020	2	293					1	265	
Fulton:																		
September				1	248	1,108												
October				2	278	1,115												
November													1	310	940			
December				1	293		1	321	874				3	293	988			
Average	9	299	983	4	273	1,112	1	321	874				4	302	964			
Garland:																		
October				2	306	1,111												
December							1	322	1,032									
January				1	267	1,064	3	318	1,010									
Average	7	304	1,055	3	287	1,088	4	320	1,021									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Grant:																		
September				1	312	1,026												
October				2	295	1,064												
November				2	311	1,051	3	318	985									
December				1	300	1,092												
January																1	270	
Average	10	298	1,022	6	305	1,058	3	318	985							1	270	
Greene:																		
September				1	249													
October				8	265		3	339	934	1	311	1,064	17	325	1,013			
November				1	303		8	317	931	1	303	1,105	28	313	991			
December				7	287		9	309	861	2	286	994	12	300	979			
January							3	297	877				4	296	959			
Average	105	300	980	17	276		23	316	901	4	300	1,054	61	309	986			
Hempstead:																		
September				7	280	1,051				21	314	985	2	331	953	2	324	1,048
October				11	289	1,073	10	325	991				1	330	899	1	321	1,051
November				24	281	1,058	9	314	988									
December				3	308	1,077	3	316	988	1	302							
January				2	295	1,039	7	315	1,004									
Average	104	314	1,003	47	291	1,060	29	318	993	22	308	985	43	330	926	3	323	1,050
Hot Spring:																		
September				1	287	1,054												
October				4	275	1,080												
November				2	281	1,130												
December				1	274	1,026												
Average	8	279	1,073	8	279	1,073												

Howard:																		
September				1	293	1,070				1	315	1,061						
October				4	290	1,055	2	299	1,036	1	285							
November				1	288	1,035	1	288	972									
January							1	342	982									
Average	12	300	1,037	6	290	1,053	4	310	997	2	300	1,061						
Independence:																		
September				4	270	1,048				3	299	1,077				1	326	1,083
October				8	281	1,064	9	320	1,004				1	310	956	2	313	1,054
November				5	286	1,051	3	295	975				1	294	944			
December				8	289	1,055	7	302	960				1	316	960			
January				2	296	1,029	7	286	925									
Average	62	302	1,023	27	284	1,049	26	301	966	3	299	1,077	3	307	953	3	320	1,069
Izard:																		
October										1	305					1	326	1,036
November										1	313							
Average	3	318	1,036							2	309					1	326	1,036
Jackson:																		
September				11	276	1,017	5	313	1,023	13	295	1,064						
October				16	287	1,026	35	319	963	2	299	1,073	12	325	959	6	311	1,074
November				13	295	998	3	312	960	2	307		35	297	972	2	288	1,016
December				4	281	1,064	3	333	969	1	326		5	290	979			
January				1	290	861	1	333					1	291	979	1	257	
Average	172	300	1,012	45	286	993	47	322	979	18	307	1,069	53	301	972	9	285	1,045
Jefferson:																		
September				20	299	1,035	15	325	1,001	26	321	1,010	5	308	994	12	329	1,042
October				36	305	997	31	329	1,010	7	312	1,029	13	323	988	4	324	1,001
November				26	303	1,032	12	320	1,010	18	327	1,001	2	299	1,026	1	303	1,054
December				25	293	1,055	6	310	1,007	24	329	1,010						
January				7	288	1,032	8	318	975	1	353	941						
Average	299	315	1,013	114	298	1,030	72	320	1,001	76	328	998	20	310	1,003	17	319	1,032
Johnson:																		
September				1	270	1,093				2	308		2	320	991	4	337	988
October				2	290	1,092	3	314	950	1	313							
November							1	349	931	2	286							
December							10	311	944	3	308	934						
January							3	312	978									
Average	34	313	991	3	280	1,093	17	322	951	8	304	934	2	320	991	4	337	988

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Lafayette:																		
September				3	263		1	304	994	2	302	1,064	1	301	855	1	275	1,061
October				9	282	1,058							5	332	947			
November				3	304	1,048	1	309	1,013				2	336	1,026			
December				3	278	1,061												
January				2	296	1,111	1	346	947									
Average	34	301	1,025	20	285	1,070	3	320	985	2	302	1,064	8	323	943	1	275	1,061
Lawrence:																		
September				12	273	1,073				3	292	978						
October				12	287	1,042	24	310	921	1	264	1,067	3	328	893			
November				16	276	1,035	19	305	884	2	289		11	300	979	4	303	1,029
December				7	295	1,048	6	300	887	3	305	922	5	288	953			
January				7	283	979	3	308	1,035				2	289	960	1	305	1,080
Average	141	296	991	54	283	1,035	52	306	932	9	288	989	21	301	946	5	304	1,055
Lee:																		
September				26	289	1,035	4	308	1,020	1	355	899	3	301	988	2	313	1,064
October				14	309	1,013	3	312	988	2	310	975	1	314	1,077			
November				5	310	991	12	324	956				1	288	937			
December				5	297	1,016												
January				11	292	1,032												
Average	90	312	1,001	61	299	1,017	19	315	988	3	333	937	5	301	1,001	2	313	1,064
Lincoln:																		
September				2	282	1,035	7	320	998	3	323	1,029	1	312	998	3	312	979
October				6	302	1,035	9	326	1,017				5	319	1,020			
November				3	312	1,067	5	322	997									
December				1	315	1,070	7	321	979	1	294	1,070						
January				1	321	1,013	4	324	978									
Average	58	313	1,015	13	306	1,044	32	323	994	4	309	1,050	6	316	1,009	3	312	979

Little River:																		
September													1	306	1,023			
October				6	295	1,051												
December							1	316	1,054									
January				2	291	1,092												
Average	10	305	1,050	8	293	1,072	1	316	1,054				1	306	1,023			
Logan:																		
September				8	292	1,058	2	314	1,067	5	290	985						
October				4	290	1,093	2	317		1	284							
November							3	317		2	288		1	303	1,045			
December							8	312	956									
January				1	289	1,054	2	285										
Average	39	297	1,025	13	290	1,068	17	309	1,012	8	287	985	1	303	1,045			
Lonoke:																		
September				8	286	1,036	3	325	1,007	17	308	1,054				24	305	985
October				6	303	1,045	10	333	979	7	302	1,036	6	310	1,036	1	288	985
November				2	316	1,048	13	317	994	2	296	1,054	2	327	1,032			
December				2	296	1,074	7	314	972	4	312	1,026						
January				4	298	1,061	4	323	928									
Average	122	309	1,018	22	300	1,053	37	322	976	30	305	1,043	8	319	1,034	25	297	985
Madison:																		
October							1	314	1,150									
November				1	291	1,194	3	333	1,017									
Average	5	308	1,139	1	291	1,194	4	324	1,084									
Marion:																		
September				2	274	1,039												
October				1	293	1,045												
November				1	311	944	1	348	912									
December							3	312	991									
January				1	312	1,048	6	327	903									
Average	15	314	977	5	298	1,019	10	329	935									
Miller:																		
September				1	292	1,073				2	314	1,055				1	314	1,026
October				7	298	1,092										1	341	1,073
November				6	306	1,074	1	352	1,207									
December							6	319	979									
January							7	325	991									
Average	32	318	1,061	14	299	1,080	14	332	1,059	2	314	1,055				2	328	1,050

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Mississippi:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				42	294	1,016	8	318	934	5	332	988	8	337	991	5	323	940
October				51	296	1,026	28	327	963				12	329	1,007	1	313	969
November				68	306	1,023	26	332	915	4	332	991	19	317	997			
December				34	307	1,051	24	330	906	2	313	941	10	303	1,004			
January				18	308	998	6	322	947	4	295	890	1	291	1,007	1	296	1,013
Average	377	314	977	213	302	1,023	92	326	933	15	318	953	50	315	1,001	7	311	974
Monroe:																		
September				10	287	1,112	1	319	1,029	7	297	1,032	2	318	966	5	314	1,001
October				6	289	1,007	6	316	1,016	1	323	1,036	10	314	1,010			
November				4	292	998	4	322	979				12	308	975			
December				4	289	1,099				8	326	921	3	283	941			
January				1	295	1,029	1	317	890									
Average	85	309	1,000	25	290	1,049	12	319	979	16	315	996	27	306	973	5	314	1,001
Montgomery:																		
September							1	319	1,055									
October				2	270	1,118	1	330	903									
December							1	338	979				1	320	915			
January										1	325	952						
Average	7	311	931	2	270	1,118	3	329	979	1	325	953	1	320	915			
Nevada:																		
September				5	276	1,032							2	312	1,001	1	261	1,146
October				1	284	1,137												
Average	9	284	1,077	6	280	1,085							2	312	1,001	1	261	1,146

Newton:																		
September													1	330	1,042			
November				1	292	1,124	2	329	1,036									
Average	4	317	1,068	1	292	1,124	2	329	1,036				1	330	1,042			
Ouachita:																		
September				5	262	1,086							2	314	991			
October				16	269	1,083							11	314	978			
November				12	269	1,051	7	314	1,036				5	304	1,007	1	334	950
December													1	289	1,017			
January				1	274	1,146												
Average	61	306	1,019	34	269	1,092	7	314	1,036				19	305	998	1	334	950
Perry:																		
September				10	289	1,073				6	284	1,013				1	301	1,020
October				9	295	1,058	8	325	922				1	319	937			
November				3	291	1,121	2	298	988	2	314		1	329	960			
December				2	311	1,108	3	313	906									
January				1	313	1,032	2	336	934									
Average	51	308	1,000	25	300	1,078	15	318	938	8	299	1,013	2	324	949	1	301	1,020
Phillips:																		
September				24	291	969	7	315	1,013	9	317	978	9	329	944	18	307	950
October				14	269	1,064	16	325	1,001	3	336	1,004	4	319	978			
November				11	290	1,058	15	316	991	1	303		3	303	1,036			
December				9	304	1,045	10	323	1,016									
January				2	292	1,077	7	306	956	1	323	1,092						
Average	163	310	1,000	60	289	1,043	55	317	995	14	320	1,025	16	317	986	18	307	950
Pike:																		
September				1	295	1,064				2	303	1,070	1	318	975			
October							3	315	1,013									
November				1	281	1,159							1	333	1,042			
December							1	336	1,105									
Average	10	311	1,063	2	288	1,112	4	326	1,059	2	303	1,070	2	326	1,009			
Poinsett:																		
September				13	288	1,048	4	318	1,007				1	281	1,036			
October				12	295	1,048	8	324	978				1	302	1,035			
November				14	306	1,058	6	327	934									
December				15	310	1,042	6	323	890				2	302	978			
January				5	293	988												
Average	87	305	1,002	59	298	1,037	24	323	952				4	295	1,016			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Polk:																		
September				9	286	1,080				1	346	960						
October							1	331	944									
November				1	335	1,118												
January				1	285	1,130												
Average	13	326	1,004	11	302	1,109	1	331	944	1	346	960						
Pope:																		
September							3	317	909	9	300	1,039	2	310	937	7	304	991
October				9	292	1,067	5	329	950	1	285							
November				5	295	1,073	18	323	928	1	311		1	336	982			
December				1	285	1,073	7	307	934									
January				2	293	1,089	4	324	922	1	281					1	233	
Average	77	299	999	17	291	1,076	37	320	929	12	294	1,039	3	323	960	8	269	991
Prairie:																		
September				1	255	1,112												
October				1	281	1,172	2	320	1,042									
November							7	318	940									
December							1	340	903									
January							3	303	994				1	276	1,010			
Average	16	288	1,041	2	268	1,142	13	320	970				1	276	1,010			
Pulaski:																		
September				8	305	1,036	1	271	921	7	307	960	1	307		14	317	953
October				6	288	1,055	6	327	1,001	2	311	1,118	7	323	960	2	333	940
November				17	295	988	2	321	960	3	306	1,134	4	322	1,004	1	301	1,010
December				6	295	1,045				3	301	1,023				1	323	988
January				6	294	988	2	326	994	1	304					2	283	1,061
Average	102	308	1,004	43	295	1,022	11	311	969	16	306	1,059	12	317	982	20	311	990

Randolph:																		
September				3	276	1,039				2	266	1,001						
October				13	288	1,096	6	333	861				5	325	959			
November				3	303	1,073	10	334	877				4	335	972			
December				4	312	1,054	3	322	871	2	301	982	3	314	994			
January				8	295	947				2	311	969	1	288	978			
Average	69	309	968	31	295	1,042	19	330	870	6	293	984	13	316	976			
St. Francis:																		
September				25	295	1,039	4	306	969	7	288	1,074	2	294	1,023	2	320	1,055
October				24	303	1,051	14	315	969				1	297	997	1	314	1,036
November				12	300	1,064	12	316	922				1	314	944			
December				6	303	1,036	4	311	906	1	304	982						
January				3	304	1,004				6	303	988	1	302	1,055			
Average	126	306	1,009	70	301	1,039	34	312	942	14	298	1,015	5	302	1,005	3	317	1,046
Saline:																		
September										1	330		1	340	960			
October				4	302	969	2	314					1	322	975			
November				5	291	1,010	2	321	928	1	319							
December				6	309	1,073												
January				2	318	1,086												
Average	25	320	977	17	305	1,035	4	318	928	2	325		2	331	968			
Scott:																		
October				2	282	1,150												
January				1	284	1,153												
Average	3	283	1,152	3	283	1,152												
Searcy:																		
November							2	345	925									
January							1	324	928									
Average	3	335	927				3	335	927									
Sebastine:																		
September				5	277	1,061	5	312	1,083	4	288	1,070	3	321	959	3	291	1,055
October				4	299	1,064	17	323	1,016	3	303	1,055				4	312	1,051
November							8	312	1,036									
December							4	325	1,020									
January				1	276	1,083	3	311	988									
Average	64	304	1,035	10	284	1,069	37	317	1,029	7	296	1,063	3	321	959	7	302	1,053
Sevier:																		
September										2	317	1,001						
November				1	330	1,092												
January				1	274	1,055	2	338	934									
Average	6	319	1,003	2	302	1,074	2	338	934	2	317	1,001						

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

ARKANSAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Sharp:																		
October				2	298	1,039												
November							2	321	918	1	294	1,115						
December							3	327	903	1	311	1,121	1	318	1,026			
Average	10	311	1,024	2	298	1,039	5	324	911	2	303	1,118	1	318	1,026			
Stone:																		
October				1	253	1,112	1	319	975									
November							2	326	941									
January							1	331	861									
Average	5	289	1,019	1	253	1,112	4	325	926									
Union:																		
September				1	274		2	324	941	3	316	922						
October				2	263		2	316	909				2	310	914			
December				3	277								2	293	953			
January				1	313	1,051												
Average	18	305	958	7	282	1,051	4	320	925	3	316	922	4	302	934			
Van Buren:																		
October				1	274	1,130												
Average	1	274	1,130	1	274	1,130												
Washington:																		
September				3	295	966	1	293	1,102									
October				1	306	1,112												
Average	5	297	1,071	4	301	1,039	1	293	1,102									

White:																		
September				8	276	1,067												
October				4	274	1,153	3	315	1,017	1	296	1,121						
November				1	280	1,108	4	285	982				2	331	950			
December							1	274	1,070									
January				2	275	1,089												
Average	26	299	1,050	15	276	1,104	8	291	1,023	1	296	1,121	2	331	950			
Woodruff:																		
September				12	280	1,042	2	301	898	5	311	1,042				3	313	966
October				8	298	1,023	8	323	966	1	311	1,067				1	298	1,083
November				6	304	1,042	15	325	934									
December				4	284	1,036	2	332	890	1	315		1	300	991			
January				5	293	997												
Average	74	306	1,040	35	292	1,028	27	320	922	7	312	1,055	1	300	991	4	306	1,025
Yell:																		
September				9	269	1,124				11	283	1,115				4	329	978
October							4	318		2	304		2	315	956			
November							6	323	975	5	306							
December							20	321	966	2	309							
January				2	280	1,058				1	314					1	274	
Average	69	303	1,022	11	275	1,091	30	321	971	21	303	1,115	2	315	956	5	302	978

CALIFORNIA.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	16	329	1,164	13	324	1,180	1	346	1,140	2	316	1,154						
Imperial	14	317	1,110	12	318	1,065				2	316	1,154						
Riverside	2	338	1,218	1	330	1,295	1	346	1,140									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

CALIFORNIA—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Imperial:																		
November										1	321	1,140						
December				3	319	1,077				1	311	1,168						
January				9	317	1,054												
Average	14	317	1,110	12	318	1,065				2	316	1,154						
Riverside:																		
November				1	330	1,295												
December							1	346	1,140									
Average	2	338	1,218	1	330	1,295	1	346	1,140									

FLORIDA.

BY COUNTIES.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	352	327	1,024	80	319	1,078	145	334	1,006	14	335	957	72	317	1,024	41	334	976
Alachua	60	336	1,020	12	326	1,059	46	334	1,029	2	347	971						
Baker	9	332	1,007				9	332	1,007									
Bradford	16	330	1,039	2	315	1,054	12	336	1,036	1	317	1,055				1	353	1,010
Calhoun	3	311	1,006										2	311	1,013	1	310	998
Citrus	2	367	1,013	1	333	1,108	1	401	918									

Columbia	31	347	1,032	12	311	1,105	16	334	1,066							3	396	925
De Soto	2	346	1,033	1	336	1,115							1	355	950			
Duval	1	300	1,036										1	300	1,036			
Escambia	1	338	1,001	1	338	1,001												
Hamilton	19	343	1,015	3	305	1,017	6	359	1,064				7	350	1,014	3	357	963
Hernando	1	279	1,036	1	279	1,036												
Hillsborough	1	314	1,140	1	314	1,140												
Holmes	2	325	917													2	325	917
Jackson	85	307	990	14	294	1,018	6	305	1,022	6	333	907	42	294	1,010	17	310	992
Jefferson	3	324	1,050										3	324	1,050			
Lafayette	4	327	1,066	1	314	1,178	1	331	1,067							2	337	953
Lake	5	328	1,002	3	320	1,104				2	336	899						
Leon	1	323	1,001													1	323	1,001
Levy	1	376	975				1	376	975									
Madison	23	332	1,025	3	307	1,080	5	340	1,046	3	341	955	6	349	1,044	6	321	1,000
Marion	25	315	1,067	2	332	1,091	22	327	1,002				1	273	1,140	1	327	1,036
Nassau	3	358	1,003				3	358	1,003									
Okaloosa	1	312	1,055	1	312	1,055												
Pasco	1	315	1,093	1	315	1,093												
Polk	4	301	1,015	3	330	1,140	1	272	890									
Santa Rosa	2	317	987				1	302	982							1	331	991
Seminole	4	320	1,078	2	319	1,075	2	321	1,080									
Sumter	4	333	1,069	4	333	1,069												
Suwannee	23	339	1,041	10	333	1,091	11	336	1,090							2	349	941
Taylor	1	307	1,013	1	307	1,013												
Volusia	1	340	1,064	1	340	1,064												
Wakulla	1	343	972				1	343	972									
Washington	11	304	929				1	311	861				9	298	963	1	302	963

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

FLORIDA—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Alachua:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				3	333	1,061	22	323	1,036	1	361	979						
October				2	316	1,042	8	337	1,016	1	333	963						
November				7	329	1,074	7	339	1,026									
December							7	337	1,045									
January							2	335	1,020									
Average	60	336	1,020	12	326	1,059	46	334	1,029	2	347	971						
Baker:																		
September							3	319	972									
October							2	353	975									
November							3	333	1,032									
January							1	324	1,048									
Average	9	332	1,007				9	332	1,007									
Bradford:																		
September							7	316	1,042									
October							1	368	1,029	1	317	1,055				1	353	1,010
November				2	315	1,054	2	332	1,048									
December							2	327	1,026									
Average	16	330	1,039	2	315	1,054	12	336	1,036	1	317	1,055				1	353	1,010
Calhoun:																		
October													2	311	1,013			
January																1	310	998
Average	3	311	1,006										2	311	1,013	1	310	998

Citrus:																		
September				1	333	1,108												
November							1	401	918									
Average	2	367	1,013	1	333	1,108	1	401	918									
Columbia:																		
September				1	279	1,023	5	331	1,121									
October				5	319	1,134	1	326	1,020									
November				5	321	1,115	1	351	1,086									
December							9	326	1,036							2	369	922
January				1	323	1,146										1	322	928
Average	31	347	1,032	12	311	1,105	16	334	1,066							3	396	925
De Soto:																		
September													1	355	950			
November				1	336	1,115												
Average	2	346	1,033	1	336	1,115							1	355	950			
Duval:																		
October													1	300	1,036			
Average	1	300	1,036										1	300	1,036			
Escambia:																		
September				1	338	1,001												
Average	1	338	1,001	1	338	1,001												
Hamilton:																		
September							2	367	1,029				6	349	1,007			
October				1	296	998												
November				2	313	1,036	3	352	1,070				1	350	1,020			
December							1	357	1,093							3	357	963
Average	19	343	1,015	3	305	1,017	6	359	1,064				7	350	1,014	3	357	963
Hernando:																		
September				1	279	1,036												
Average	1	279	1,036	1	279	1,036												
Hillsborough:																		
October				1	314	1,140												
Average	1	314	1,140	1	314	1,140												
Holmes:																		
November																1	335	969
December																1	314	864
Average	2	325	917													2	325	917

TABLE VI.—*Yields of oil and meal, by counties, as compiled by analyses*—Continued.

FLORIDA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Jackson:																		
September				9	299	1,016	4	304	1,039	2	340	884	16	296	1,010	7	306	988
October				5	289	1,020	1	288	998	3	338	934	11	306	1,020	5	309	1,010
November							1	324	1,029				9	299	1,001			
December										1	321	903	6	275	1,010	5	314	979
Average	85	307	990	14	294	1,018	6	305	1,022	6	333	907	42	294	1,010	17	310	992
Jefferson:																		
September													1	320	1,067			
October													2	228	1,032			
Average	3	324	1,050										3	324	1,050			
Lafayette:																		
September							1	331	1,067									
November				1	314	1,178												
December																2	337	953
Average	4	327	1,066	1	314	1,178	1	331	1,067							2	337	953
Lake:																		
October				2	345	1,096												
December				1	295	1,111				2	336	899						
Average	5	328	1,002	3	320	1,104				2	336	899						
Leon:																		
September																1	323	1,001
Average	1	323	1,001													1	323	1,001

Levy:																		
October							1	376	975									
Average	1	376	975				1	376	975									
Madison:																		
September							1	343	1,026	2	349	940				2	329	985
October				1	295	1,039	3	326	1,048	1	333	969	2	328	1,042			
November				1	294	1,073							2	355	1,092			
December							1	352	1,064				2	364	998	3	336	979
January				1	333	1,127										1	297	1,036
Average	23	332	1,025	3	307	1,080	5	340	1,046	3	341	955	6	349	1,044	6	321	1,001
Marion:																		
September							8	316	988									
October				1	337	1,099	9	319	1,001							1	327	1,036
November				1	327	1,083	2	348	998				1	273	1,140			
December							3	326	1,020									
Average	25	315	1,067	2	332	1,091	22	327	1,002				1	273	1,140	1	327	1,036
Nassau:																		
October							2	317	979									
November							1	399	1,026									
Average	3	358	1,003				3	358	1,003									
Okaloosa:																		
September				1	312	1,055												
Average	1	312	1,005	1	312	1,055												
Pasco:																		
November				1	315	1,093												
Average	1	315	1,093	1	315	1,093												
Polk:																		
September							1	272	890									
October				2	328	1,169												
January				1	332	1,111												
Average	4	301	1,015	3	330	1,140	1	272	890									
Santa Rosa:																		
October																1	331	991
November							1	302	982									
Average	2	317	987				1	302	982							1	331	991

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

FLORIDA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Seminole:																		
September				1	316	1,051	1	336	1,089									
November				1	322	1,099												
December							1	306	1,070									
Average	4	320	1,078	2	319	1,075	2	321	1,080									
Sumter:																		
October				2	322	1,096												
November				2	344	1,042												
Average	4	333	1,069	4	333	1,069												
Suwannee:																		
September							5	328	1,108									
October				9	318	1,108	1	327	1,064									
November				1	348	1,073	4	341	1,074									
December							1	347	1,115							2	349	941
Average	23	339	1,041	10	333	1,091	11	336	1,090							2	349	941
Taylor:																		
October				1	307	1,013												
Average	1	307	1,013	1	307	1,013												
Volusia:																		
November				1	340	1,064												
Average	1	340	1,064	1	340	1,064												
Wakulla:																		
September							1	343	972									
Average	1	343	972				1	343	972									

Washington:																		
September							1	311	861				1	299	937			
October													8	297	988			
January																1	302	963
Average	11	304	929				1	311	861				9	298	963	1	302	963

GEORGIA.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	14,083	321	948	4,194	307	977	2,359	317	945	2,572	332	900	2,343	323	969	2,615	328	932
Appling	47	321	966	12	285	1,020	9	304	988	2	337	966	1	348	947	23	332	910
Atkinson	2	294	1,000	2	294	1,000												
Bacon	25	339	1,021	8	292	1,040	6	328	1,000	1	376	1,001	4	350	1,118	6	351	948
Baker	3	337	932				2	349	958				1	325	906			
Baldwin	67	327	945	28	324	946	2	331	934	9	340	892	16	306	989	12	333	966
Banks	22	321	908	9	318	937	8	319	888	4	322	850	1	323	956	4		
Barrow	39	324	920	5	324	979	10	314	914	16	338	858	4	327	910		319	938
Bartow	290	317	922	56	299	970	27	313	913	137	323	878	43	327	941	27	325	909
Ben Hill	13	319	964	3	314	997	4	339	966	3	343	922	1	278	937	2	323	998
Berrien	73	338	1,005	14	300	1,025	7	312	1,061	1	390	969	27	338	1,030	24	350	938
Bibb	54	324	944	5	301	978	1	331	950	11	328	894	18	318	975	19	342	945
Bleckley	22	330	934	4	297	980	1	372	950	4	334	873	7	316	968	6	331	897
Brooks	44	324	966	14	297	1,042	7	312	951	14	332	939	3	354	952	6	327	947
Bryan	44	302	1,003	13	301	1,010	31	302	995									
Bulloch	199	319	959	93	300	1,017	72	314	997	8	326	922	5	321	969	21	335	890
Burke	410	328	929	136	311	936	35	318	961	66	335	911	49	332	918	124	343	921
Butts	179	319	925	63	304	934	25	316	922	64	330	868	16	325	960	11	319	942
Calhoun	58	325	981	22	305	1,010	4	321	953	7	350	969	19	317	1,028	6	332	946
Camden	13	329	956				8	322	1,001	1	346	833	2	328	974	2	319	1,014
Campbell	109	324	921	28	309	961	25	321	895	25	334	876	23	328	949	8	330	924

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Candler	54	327	975	18	302	1,015	6	325	980	15	329	915	9	332	1,013	6	348	950
Carroll	50	331	913	13	321	960	8	326	851	9	337	901	10	331	922	10	339	933
Catoosa	10	313	935	.....	.....	.....	1	295	902	1	314	906	3	320	1,005	5	323	926
Charlton	18	333	1,015	.....	.....	.....	16	309	1,033	.....	.....	.....	2	357	996	.....	.....	.....
Chatham	114	319	940	48	306	990	21	315	954	1	309	925	43	363	938	1	302	893
Chattahoochee	23	318	929	3	304	969	4	308	884	5	340	911	2	321	947	9	315	934
Chattooga	14	306	908	4	296	1,015	1	281	842	1	307	899	4	328	930	4	318	955
Cherokee	19	328	900	6	340	943	4	307	844	4	341	903	5	325	909	.....	.....	.....
Clarke	124	321	944	71	307	951	19	312	908	25	340	904	6	323	971	3	322	984
Clay	40	324	924	4	283	925	14	318	921	2	365	903	11	324	971	9	330	902
Clayton	110	330	918	37	316	946	11	327	942	32	334	888	22	332	939	8	343	876
Clinch	9	309	967	2	294	952	2	291	955	.....	.....	.....	4	318	1,028	1	313	934
Cobb	106	331	919	35	324	951	11	318	890	17	334	895	28	328	941	15	349	916
Coffee	114	318	987	23	293	1,028	38	315	1,051	16	334	921	18	320	974	19	329	960
Colquitt	55	318	969	18	300	1,013	12	307	1,012	2	339	896	17	316	993	6	330	933
Columbia	158	328	958	35	312	993	7	320	968	35	334	912	25	333	982	56	343	937
Coweta	228	320	909	113	302	926	24	325	926	42	328	884	25	327	918	24	317	892
Cook	1	302	1,055	1	302	1,055	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Crawford	71	316	955	26	307	996	6	297	981	10	337	897	9	320	965	20	321	934
Crisp	162	319	930	16	304	988	26	323	935	26	329	823	15	313	984	79	327	919
Dade	3	317	991	1	316	1,115	1	319	950	.....	.....	.....	.....	.....	.....	1	317	909
Decatur	35	307	1,001	12	290	1,066	7	309	932	8	329	980	5	304	1,060	3	302	969
Dekalb	100	319	929	54	313	951	17	315	916	10	328	868	18	332	952	1	308	956
Dodge	234	315	946	53	304	966	21	309	985	36	328	877	63	310	975	61	326	927
Dooly	128	316	930	14	297	974	27	304	908	20	325	887	42	322	950	25	333	932

Dougherty	96	332	960	43	312	949	4	333	979	16	346	933	24	321	983	9	348	958
Douglas	36	332	906	6	312	906	4	327	909	15	335	868	3	333	915	8	351	930
Early	128	315	987	17	299	1,035	11	315	967	11	326	910	54	305	1,056	28	331	969
Echols	2	319	949				1	326	925				1	312	972			
Effingham	51	316	989	17	298	1,004	33	313	976				1	337	988			
Elbert	248	318	926	56	308	956	47	319	880	50	328	882	42	318	968	53	316	944
Emanuel	390	321	941	107	301	960	76	315	969	57	325	918	59	325	959	91	338	899
Evans	43	329	986	31	296	984	9	340	1,008	1	332	915	2	348	1,036			
Fannin	7	323	939				3	324	950	4	322	927						
Fayette	54	318	911	15	308	937	8	306	899	17	326	862	8	324	938	6	327	917
Floyd	52	318	926	35	299	987	8	311	876	3	341	868	2	325	930	4	313	971
Franklin	164	311	906	95	303	933	21	308	854	29	321	874	17	321	949	2	301	922
Fulton	34	322	914	19	313	971	4	334	901	6	318	877	3	313	903	2	334	917
Gilmer	1	325	985	1	325	985												
Glascock	16	320	969	8	305	936	4	326	979				4	328	991			
Glynn	1	262	1,073				1	262	1,073									
Gordon	62	322	928	21	314	988	6	312	893	21	338	886	10	321	906	4	325	969
Grady	11	314	1,002	6	297	1,080				2	327	931	2	298	1,045	1	332	953
Greene	161	321	928	55	316	951	14	324	933	29	326	873	37	317	951	26	323	934
Gwinnett	163	327	910	74	318	956	32	325	880	38	335	868	11	331	938	8	325	909
Habersham	10	332	923	8	315	946	1	360	921	1	322	903						
Hall	120	324	928	45	318	944	25	314	899	29	332	875	15	325	969	6	332	951
Hancock	443	320	918	80	308	913	4	311	922	90	331	886	108	323	972	161	326	897
Haralson	12	325	919	6	326	986				4	331	889				2	318	883
Harris	110	321	925	27	307	968	11	328	898	34	331	895	23	322	932	15	317	930
Hart	93	318	919	17	305	980	16	319	880	18	325	881	18	328	919	24	313	933
Heard	2	320	1,015							1	342	975	1	297	1,055			
Henry	158	324	911	70	305	932	26	312	897	19	331	857	22	335	917	21	335	950
Houston	135	327	955	42	302	991	7	327	968	23	329	904	11	341	994	52	335	919
Irwin	17	311	938	4	316	1,000	7	302	972	1	325	906	2	293	931	3	317	882
Jackson	132	316	918	50	306	911	32	311	917	11	327	895	26	305	952	13	330	914
Jasper	190	324	932	72	321	969	20	324	929	30	330	881	48	311	963	20	332	916
Jeff Davis	55	310	951	43	300	991	4	291	972	3	320	912	4	327	960	1	310	921
Jefferson	166	324	957	48	312	988	45	315	989	14	332	918	21	331	975	38	330	916
Jenkins	247	325	946	57	300	984	24	313	979	48	337	909	26	333	936	92	341	922
Johnson	54	325	927	19	319	957	15	313	954	6	330	886	6	329	941	8	333	898
Jones	82	330	928	14	328	946	8	332	911	25	342	877	21	319	985	14	329	919
Laurens	215	325	948	98	310	975	18	315	949	26	330	907	40	327	981	33	342	926
Lee	120	328	962	19	306	963	18	330	964	25	342	921	23	323	1,007	35	338	955
Liberty	18	305	949	6	291	999	10	314	973	2	310	874						
Lincoln	19	311	977	11	290	992							7	345	1,036	1	298	902
Lowndes	63	343	983	12	306	996	11	334	1,011	4	371	938	9	353	1,040	27	350	930
Lumpkin	2	324	901													2	324	901
McDuffie	138	317	932	36	309	973	16	316	954	11	325	880	36	314	954	39	323	899
McIntosh	11	309	960				5	308	935				2	294	1,036	4	326	908

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Macon	70	321	943	26	306	974	16	312	942	7	328	904	8	321	991	13	338	904
Madison	53	316	919	13	297	949	12	319	896	19	334	902	7	316	896	2	313	953
Marion	68	322	934	10	301	954	24	322	933	7	338	898	13	321	966	14	327	920
Meriwether	175	322	904	38	312	929	23	320	873	31	330	854	48	325	938	35	324	925
Miller	14	304	1,000	3	300	1,042	1	280	991	2	333	906	7	286	1,065	1	322	994
Milton	1	307	1,007	1	307	1,007												
Mitchell	42	314	996	16	289	1,021	13	302	1,006	4	341	919	7	307	1,042	2	333	994
Monroe	116	320	943	39	302	961	16	323	916	24	328	879	17	321	986	20	328	974
Montgomery	162	318	949	70	305	972	38	307	953	9	331	922	19	321	961	26	326	938
Morgan	300	318	909	94	312	927	49	320	897	65	325	880	47	315	939	45	320	903
Murray	25	321	904	13	313	955	1	320	864	7	328	903				4	322	895
Muscogee	264	315	946	77	296	979	78	319	936	55	332	899	41	320	955	13	309	961
Newton	220	318	910	70	318	938	45	318	911	43	324	858	37	312	927	25	319	921
Oconee	78	324	931	25	310	956	15	322	911	16	332	884	11	334	971	11	324	931
Oglethorpe	100	323	911	51	313	922	19	317	918	10	340	879	9	324	941	11	321	896
Paulding	25	325	907	15	314	933	4	314	917	3	342	846				3	328	933
Pickens	8	350	967	2	327	1,031	2	339	960	3	333	941				1	320	934
Pierce	35	333	1,013	9	309	1,068	22	336	1,045	1	359	1,064	2	317	906	1	346	982
Pike	241	316	925	75	296	946	39	317	913	51	326	881	35	320	938	41	319	945
Polk	77	316	915	36	292	968	9	303	868	16	329	882	4	337	941	12	321	915
Pulaski	105	323	932	12	299	957	13	337	937	15	328	881	24	317	978	41	332	905
Putnam	136	324	922	54	324	935	33	319	905	16	330	893	21	316	953	12	330	925
Quitman	5	341	943							1	352	934	4	329	952			
Rabun	8	325	957	1	307	915	5	321	944							2	347	1,012
Randolph	102	326	971	19	297	978	18	324	979	23	339	909	19	339	1,019	23	330	968

Richmond	269	317	979	85	301	1,022	27	311	986	43	319	956	65	325	995	49	329	935
Rockdale	22	333	921	10	326	960	6	315	893	4	336	892	1	333	931	1	356	928
Schley	15	328	941	5	313	983	1	348	934	8	332	906	1	317	940	.....	.....	.....
Screven	247	328	936	88	303	983	113	315	951	19	340	913	5	333	937	22	349	898
Spalding	64	314	963	35	299	992	3	309	1,002	14	325	882	6	305	969	6	330	970
Stephens	54	312	929	13	311	911	22	304	920	9	326	865	9	323	928	1	296	1,020
Stewart	93	328	958	11	322	985	5	333	949	37	335	912	16	324	994	24	326	949
Sumter	163	329	953	14	326	956	26	319	937	28	340	932	32	323	1,005	63	338	936
Talbot	83	316	939	14	294	981	15	317	921	24	327	893	14	320	968	16	322	934
Taliaferro	148	321	912	30	303	945	11	323	913	27	329	865	48	322	934	32	326	905
Tattnall	120	331	969	55	310	1,037	44	320	979	5	334	902	5	337	971	11	354	956
Taylor	100	319	950	24	300	1,002	19	317	927	20	330	899	11	319	985	26	328	939
Telfair	222	315	963	62	298	994	22	306	978	17	328	911	25	316	1,000	96	325	930
Terrell	233	327	969	31	317	980	25	326	969	119	339	937	24	324	1,023	34	330	938
Thomas	39	321	974	11	298	1,018	4	317	969	4	330	920	15	317	1,014	5	342	947
Tift	87	320	984	19	300	1,002	18	313	995	16	326	956	28	311	1,009	6	348	956
Tombs	56	327	973	10	307	983	38	311	966	.....	.....	.....	5	330	957	3	361	984
Troup	132	318	916	29	313	942	33	313	899	29	320	888	23	317	912	18	324	937
Turner	175	314	948	21	297	978	34	323	963	36	320	911	40	305	980	44	325	910
Twiggs	136	326	935	58	306	960	3	335	934	33	328	900	20	325	985	22	334	898
Upson	56	317	939	5	302	987	13	326	939	20	324	868	9	315	953	9	320	947
Walker	13	313	973	6	309	1,021	2	302	1,069	1	315	880	2	318	1,001	2	323	895
Walton	138	318	903	35	304	955	51	320	900	24	329	863	16	319	913	12	318	883
Ware	45	319	968	24	302	986	15	312	1,015	1	319	925	2	313	974	3	351	941
Warren	172	325	894	13	308	903	.....	.....	.....	51	332	862	41	326	934	67	332	875
Washington	80	332	950	33	321	940	18	318	969	12	343	899	12	337	981	5	343	963
Wayne	50	323	980	21	292	1,026	9	342	1,040	3	326	901	9	330	1,009	8	327	922
Webster	25	327	950	3	316	979	3	323	919	12	332	922	3	329	1,016	4	337	915
Wheeler	99	323	938	28	308	984	8	327	945	9	329	893	25	319	936	29	332	934
White	2	335	939	.....	.....	.....	.....	.....	.....	1	329	887	1	340	991	.....	.....	.....
Whitfield	12	328	961	7	324	1,054	1	293	931	1	358	883	3	338	975	.....	.....	.....
Wilcox	240	314	959	44	298	987	46	314	942	58	326	927	30	303	1,009	62	329	929
Wilkes	63	319	923	21	313	937	6	312	925	11	331	873	15	315	935	10	322	946
Wilkinson	46	323	935	21	301	964	2	312	916	9	337	903	7	322	966	7	343	928
Worth	136	315	944	27	302	965	24	300	968	25	327	903	20	319	969	40	328	913

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Appling:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				11	282	988	3	292	994							8	331	874
October							1	317	1,020							1	333	925
November				1	287	1,051	3	314	1,020				1	348	947	3	328	899
December							1	295	956							5	339	937
January							1	303	950	2	337	966				6	327	915
Average	47	321	966	12	285	1,020	9	304	988	2	337	966	1	348	947	23	332	910
Atkinson:																		
November				1	293	1,096												
December				1	295	1,004												
Average	2	294	1,000	2	294	1,000												
Bacon:																		
September				2	287	1,036	1	310	1,013				3	310	1,051	1	309	950
October				1	278	934	2	337	1,051	1	376	1,001	1	390	1,184	1	366	944
November				4	295	1,035	2	352	1,061							1	351	928
December				1	308	1,156										1	397	988
January							1	312	874							2	333	931
Average	25	339	1,021	8	292	1,040	6	328	1,000	1	376	1,001	4	350	1,118	6	351	948
Baker:																		
September							1	346	934				1	325	906			
December							1	352	982									
Average	3	337	932				2	349	958				1	325	906			

Baldwin:																		
September				5	306	925	2	331	934	5	343	861	8	324	1,035	1	346	969
October				6	326	922				3	333	884	7	316	978	6	322	947
November				11	325	956							1	279	953			
December				3	323	969				1	344	931				5	330	982
January				3	338	956												
Average	67	327	945	28	324	946	2	331	934	9	340	892	16	306	989	12	333	966
Banks:																		
September				1	304	959				1	330	792	1	323	956			
October				1	323	902	1	331	887	2	322	884						
November				4	323	963	5	338	893									
January				3	322	922	2	288	883	1	314	874						
Average	22	321	908	9	318	937	8	319	888	4	322	850	1	323	956			
Barrow:																		
September							1	304	969	2	342	861	2	319	921	1	314	909
October				2	323	985							2	334	899	2	316	960
November				3	325	972	4	328	918	1	336	817						
December							1	321	887	6	335	890						
January							4	302	880	7	337	865				1	328	944
Average	39	324	920	5	324	979	10	314	914	16	338	858	4	327	910	4	319	938
Bartow:																		
September				7	285	975	9	326	903	26	323	852	7	346	906	8	317	906
October				20	297	972	8	307	953	28	333	871	28	332	931	2	307	903
November				15	309	960	6	306	903	37	324	899	7	315	915	16	337	931
December				9	308	960	4	314	893	29	323	893				1	340	896
January				5	297	985				17	314	874	1	313	1,013			
Average	290	317	922	56	299	970	27	313	913	137	323	878	43	327	941	27	325	909
Ben Hill:																		
September				3	314	997	4	339	966	2	328	890				2	323	998
November													1	278	937			
December										1	357	953						
Average	13	319	964	3	314	997	4	339	966	3	343	922	1	278	937	2	323	998
Berrien:																		
September				5	289	1,004	7	312	1,061	1	390	969	22	328	998	1	333	947
October				2	291	1,029							1	314	956	1	387	903
November				5	312	1,0[illegible]9							1	368	1,093	4	367	950
December				1	315	1,061							3	342	1,074	11	331	950
January				1	292	944										7	334	940
Average	73	338	1,005	14	300	1,025	7	312	1,061	1	390	969	27	338	1,030	24	350	938

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Bibb:																		
September				1	307	988				4	336	864	7	322	953	8	346	966
October				3	296	994				3	343	899	8	309	950	6	337	940
November							1	331	950	2	318	944	3	323	1,023	2	324	921
December										1	308	884				2	374	978
January				1	299	953				1	336	880				1	327	921
Average	54	324	944	5	301	978	1	331	950	11	328	894	18	318	975	19	342	945
Bleckley:																		
September							1	372	950	2	344	877	3	321	988			
October										2	323	868	4	310	947	2	316	877
November				3	297	1,013										1	346	922
December				1	296	947										2	332	877
January																1	330	912
Average	22	330	934	4	297	980	1	372	950	4	334	873	7	316	968	6	331	897
Brooks:																		
September				4	299	988	3	311	1,004	7	330	915				1	315	963
October				7	306	1,051	3	306	998	6	333	941	2	340	947	3	329	979
November				2	305	1,067												
December				1	278	1,061	1	319	852	1	333	960				2	337	899
January													1	368	956			
Average	44	324	966	14	297	1,042	7	312	951	14	332	939	3	354	952	6	327	947
Bryan:																		
September				7	301	950	10	301	991									
October							6	299	991									
November				4	314	1,001	9	302	994									
December				1	299	1,051												
January				1	289	1,039	6	306	1,004									
Average	44	302	1,003	13	301	1,010	31	302	995									

Bulloch:																		
September	.....	.....	.....	27	296	944	8	322	1,016	3	340	887	3	330	1,007	5	341	861
October	.....	.....	.....	14	296	1,016	18	308	972	2	322	931	1	334	960	3	335	868
November	.....	.....	.....	27	302	1,029	17	301	979	.....	.....	.....	.....	.....	.....	4	343	902
December	.....	.....	.....	12	292	1,039	11	318	1,007	3	315	947	1	300	941	3	328	903
January	.....	.....	.....	13	313	1,055	18	322	1,010	.....	.....	.....	.....	.....	.....	6	330	918
Average	199	319	959	93	300	1,017	72	314	997	8	326	922	5	321	969	21	335	890
Burke:																		
September	.....	.....	.....	60	317	928	12	333	978	14	356	899	26	336	922	41	348	922
October	.....	.....	.....	23	315	953	8	321	969	17	335	884	22	358	937	37	345	912
November	.....	.....	.....	30	309	960	6	321	979	7	328	947	1	322	896	26	339	918
December	.....	.....	.....	16	304	864	7	315	960	19	335	906	.....	.....	.....	12	341	928
January	.....	.....	.....	7	308	975	2	301	921	9	323	921	.....	.....	.....	8	342	925
Average	410	328	929	136	311	936	35	318	961	66	335	911	49	332	918	124	343	921
Butts:																		
September	.....	.....	.....	3	305	950	13	310	906	6	322	846	9	329	947	5	324	937
October	.....	.....	.....	13	305	918	7	313	902	4	334	883	4	318	941	1	317	931
November	.....	.....	.....	13	312	934	4	316	903	22	330	883	3	329	991	1	313	947
December	.....	.....	.....	23	297	944	1	323	978	30	324	874	.....	.....	.....	3	306	896
January	.....	.....	.....	11	300	925	.....	.....	.....	2	340	852	.....	.....	.....	1	336	997
Average	179	319	925	63	304	934	25	316	922	64	330	868	16	325	960	11	319	942
Calhoun:																		
September	.....	.....	.....	8	306	1,001	3	318	1,004	6	345	931	11	318	1,029	3	323	1,017
October	.....	.....	.....	7	298	1,010	.....	.....	.....	.....	.....	.....	6	314	1,020	3	340	874
November	.....	.....	.....	7	312	1,020	1	324	902	.....	.....	.....	1	309	1,064	.....	.....	.....
December	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	355	1,007	1	327	997	.....	.....	.....
Average	58	325	981	22	305	1,010	4	321	953	7	340	969	19	317	1,028	6	332	946
Camden:																		
September	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	346	833	1	342	947	1	315	982
October	.....	.....	.....	.....	.....	.....	3	313	944	.....	.....	.....	.....	.....	.....	.....	.....	.....
November	.....	.....	.....	.....	.....	.....	2	334	1,036	.....	.....	.....	.....	.....	.....	.....	.....	.....
December	.....	.....	.....	.....	.....	.....	3	319	1,023	.....	.....	.....	1	313	1,001	1	323	1,045
Average	13	329	956	.....	.....	.....	8	322	1,001	1	346	833	2	328	974	2	318	1,014
Campbell:																		
September	.....	.....	.....	3	299	988	2	335	921	6	344	836	9	329	902	4	323	915
October	.....	.....	.....	8	320	972	11	323	909	10	334	852	7	332	887	1	313	912
November	.....	.....	.....	8	314	966	9	327	880	4	321	906	6	326	956	1	336	953
December	.....	.....	.....	4	310	931	.....	.....	.....	4	319	884	1	323	1,051	.....	.....	.....
January	.....	.....	.....	5	303	950	3	299	868	1	353	903	.....	.....	.....	2	347	915
Average	109	324	921	28	309	961	25	321	895	25	334	876	23	328	949	8	330	924

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Candler:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				5	302	940	3	309	972	4	344	922	3	314	988			
October				2	303	1,017	1	333	944	2	343	903	2	323	998	2	346	941
November				7	303	1,064				5	333	931	2	344	1,004	1	360	944
December				3	295	985	2	334	1,023	3	309	956	1	331	1,073	1	340	950
January				1	305	1,067				1	315	865	1	348	1,001	2	344	966
Average	54	327	975	18	302	1,015	6	325	980	15	329	915	9	332	1,013	6	348	950
Carroll:																		
September				6	314	991				2	344	903	3	323	903	1	364	1,020
October				2	329	963	6	334	884	2	335	909	3	334	903	1	333	871
November				4	321	941	1	343	880	2	343	887	4	336	960	3	333	925
December							1	302	788	3	324	906				5	327	915
January				1	319	944												
Average	50	331	913	13	321	960	8	326	851	9	337	901	10	331	922	10	339	933
Catoosa:																		
September													1	288	1,006			
October													1	344	982	1	319	884
November													1	328	1,026			
December																2	320	915
January							1	295	902	1	314	906				2	329	978
Average	10	313	935				1	295	902	1	314	906	3	320	1,005	5	323	926
Charlton:																		
September							2	304	1,042									
October							7	302	1,001				1	357	959			
November							6	308	982									
December													1	357	1,032			
January							1	323	1,108									
Average	18	333	1,015				16	309	1,033				2	357	996			

Chatham:																		
September				2	294	950	5	325	991				36	358	953			
October				42	308	985	1	311	941				7	368	922			
November				1	329	998	5	317	969	1	309	925						
December				2	290	978	5	312	940							1	302	893
January				1	307	1,039	5	310	928									
Average	114	319	940	48	306	990	21	315	954	1	309	925	43	363	938	1	302	893
Chattahooche:																		
September				1	306	928							2	321	947			
October				1	304	998	1	307	864							2	320	937
November				1	302	982				3	349	893				3	312	921
December										2	330	928						
January							3	309	903							4	312	944
Average	23	318	929	3	304	969	4	308	884	5	340	911	2	321	947	9	315	934
Chattooga:																		
September				1	305	998				1	307	899						
October				2	292	994							2	347	934	1	317	814
November													2	309	925	1	319	928
December				1	291	1,054	1	281	842									
January																2	319	922
Average	14	306	908	4	296	1,015	1	281	842	1	307	899	4	328	930	4	318	855
Cherokee:																		
September													1	321	899			
October				1	355	953	1	327	855				4	329	918			
November							1	281	792									
December				1	336	947				4	341	903						
January				4	329	928	2	314	884									
Average	19	328	900	6	340	943	4	307	844	4	341	903	5	325	909			
Clarke:																		
September				7	300	991	2	324	931	6	348	877	2	325	966			
October				28	316	941	5	330	906	7	336	887	3	326	960	2	307	903
November				29	317	934	7	319	931	7	342	912	1	319	988			
December				2	302	969	3	303	893	5	333	940				1	337	1,064
January				5	299	922	2	282	877									
Average	124	321	944	71	307	951	19	312	908	25	340	904	6	323	971	3	322	984
Clay:																		
September				2	297	877	14	318	921	1	381	912	7	318	1,035			
October													3	331	998	4	323	865
November													1	324	880	1	333	925
December				1	279	956				1	348	893				4	333	915
January				1	273	941												
Average	40	324	924	4	283	925	14	318	921	2	365	903	11	324	971	9	330	902

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Clayton:																		
September				10	305	937	1	366	979	7	347	874	10	333	950	4	343	896
October				13	324	944	1	304	982	11	338	874	5	336	918	1	352	830
November				5	313	950	7	326	909	4	323	899	5	333	931	3	334	903
December				3	311	960	1	315	959	7	329	899	2	324	956			
January				6	327	940	1	323	883	3	334	893						
Average	110	330	918	37	316	946	11	327	942	32	334	888	22	332	939	8	343	876
Clinch:																		
September													3	339	1,020			
October				1	288	972	1	291	1,020				1	296	1,035			
November							1	291	890									
December				1	300	931										1	313	934
Average	9	309	967	2	294	952	2	291	955				4	318	1,028	1	313	934
Cobb:																		
September				15	326	953				2	342	858	4	341	940	1	344	918
October										2	341	931	20	328	934	4	337	884
November				6	335	975	4	322	880	6	333	906	2	327	947	7	338	899
December				7	322	928	2	326	925	3	332	896	2	317	944	2	355	928
January				7	314	947	5	305	865	4	324	884				1	371	953
Average	106	331	919	35	324	951	11	318	890	17	334	895	28	328	941	15	349	916
Coffee:																		
September				10	291	975	25	293	1,016	8	336	918	12	319	997	1	335	978
October				4	303	1,048	6	306	1,048	4	336	928	4	320	979	1	332	944
November				2	290	1,045	3	344	1,093				1	342	978			
December				6	286	1,045	2	315	1,010	4	331	918				10	324	960
January							2	316	1,089				1	300	940	7	323	959
Average	114	318	987	23	293	1,028	38	315	1,051	16	334	921	18	320	974	19	329	960

Colquitt:																		
September				6	297	1,001	9	305	991	2	339	896	10	311	1,045	1	327	899
October				3	312	1,036	2	301	1,010				5	323	978	1	333	934
November				5	287	1,004	1	315	1,036				1	304	988			
December				4	304	1,010							1	326	960	1	322	972
January																3	338	928
Average	55	318	969	18	300	1,013	12	307	1,012	2	339	896	17	316	993	6	330	933
Columbia:																		
September				14	316	1,001	4	323	975	13	350	884	15	342	934	16	345	944
October				11	309	978	1	315	979	9	348	906	8	334	947	14	339	928
November				3	302	1,001				8	339	931	1	322	1,029	12	338	937
December				3	318	1,010	2	321	950	4	315	922				9	341	953
January				4	315	975				1	318	915	1	332	1,017	5	352	925
Average	158	328	958	35	312	993	7	320	968	35	334	912	25	333	982	56	343	937
Cook:																		
November				1	302	1,055												
Average	1	302	1,055	1	302	1,055												
Coweta:																		
September				23	293	931	4	344	953	10	340	845	17	327	890	5	329	921
October				36	313	915	15	316	922	2	332	868	6	331	884	4	318	893
November				16	309	928	5	314	903	15	331	890	1	318	975	6	330	884
December				23	299	931				14	318	890	1	331	922	4	328	912
January				15	296	925				1	321	928				5	281	849
Average	228	320	909	113	302	926	24	325	926	42	328	884	25	327	918	24	317	892
Crawford:																		
September				10	312	975				4	347	903	4	329	953	6	332	928
October				8	314	982	1	303	915	3	337	880	3	313	925	5	323	941
November				3	310	1,013	1	307	959							3	319	921
December				2	295	1,010	2	293	1,007	3	327	909	2	317	1,017	2	319	950
January				3	305	998	2	284	1,042							4	314	931
Average	71	316	955	26	307	996	6	297	981	10	337	897	9	320	965	20	321	934
Crisp:																		
September				4	300	985	13	318	953	6	332	909	12	312	969	15	333	915
October				6	315	982	5	313	956	4	332	880				9	335	915
November				6	298	998	6	332	890	7	326	915				18	322	921
December							2	329	941	8	324	896	2	318	978	33	328	925
January										1	331	915	1	308	1,004	4	318	921
Average	162	319	930	16	304	988	26	323	935	26	329	823	15	313	984	79	327	919
Dade:																		
October				1	316	1,115	1	319	950							1	317	909
Average	3	317	991	1	316	1,115	1	319	950							1	317	909

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Decatur:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				3	293	1,058	1	316	934	2	333	947	1	302	1,115	1	289	972
October				6	296	1,054	3	312	861	6	325	1,013	4	306	1,004	2	314	966
November				2	295	1,099	2	320	934									
December				1	276	1,054	1	286	997									
Average	35	307	1,001	12	290	1,066	7	309	932	8	329	980	5	304	1,060	3	302	969
Dekalb:																		
September				5	297	997							3	339	966			
October				24	308	966	4	313	915	3	339	830	8	332	925			
November				10	319	944	8	333	896	3	328	899	7	326	966			
December				5	323	902	2	315	1,004	2	327	880						
January				10	319	947	3	298	849	2	318	861				1	308	956
Average	100	319	929	54	313	951	17	315	916	10	328	868	18	332	952	1	308	956
Dodge:																		
September				21	307	940	12	318	944	10	338	871	19	321	979	10	328	956
October				15	300	960				8	330	871	6	316	953	9	323	928
November				6	305	963	1	317	1,026	7	319	877	1	307	1,026	5	332	909
December				9	309	969	3	296	1,007	7	330	865	35	308	956	14	320	921
January				2	301	997	5	306	963	4	321	899	2	296	959	23	326	922
Average	234	315	946	53	304	966	21	309	985	36	328	877	63	310	975	61	326	927
Dooly:																		
September				8	292	937	16	307	890	9	331	861	32	317	950	8	336	918
October				2	281	941	7	292	893	7	338	880	7	321	959	9	327	909
November				2	295	1,039	4	312	941				3	328	940	1	336	937
December										2	307	902				4	323	928
January				2	318	978				2	322	906				3	341	966
Average	128	316	930	14	297	974	27	304	908	20	325	887	42	322	950	25	333	932

Dougherty:																		
September				40	295	988	3	351	998	11	346	896	20	323	988	6	334	947
October							1	314	959	2	337	937	4	318	978			
November				2	338	979				1	365	978						
December				1	303	880				2	336	922				1	355	1,004
January																2	354	922
Average	96	332	960	43	312	949	4	333	979	16	346	933	24	321	983	9	348	958
Douglas:																		
September										2	349	858				1	345	960
October				1	313	820	3	330	934	1	352	808	3	333	915	1	383	1,010
November				2	314	941				6	323	890				2	336	874
December				1	309	883				3	330	902				3	330	899
January				2	312	978	1	323	884	3	321	884				1	361	906
Average	36	332	906	6	312	906	4	327	909	15	335	868	3	333	915	8	351	930
Early:																		
September				9	295	1,042	9	314	997	5	324	884	32	309	1,048	14	323	982
October				5	309	998				3	330	921	21	297	1,036	6	309	950
November				1	302	1,051	1	299	921	1	327	918				4	340	959
December				2	291	1,048	1	331	982	2	321	918				2	351	979
January													1	308	1,083	2	331	975
Average	128	315	987	17	299	1,035	11	315	967	11	326	910	54	305	1,056	28	331	969
Echols:																		
September													1	312	972			
November							1	326	925									
Average	2	319	949				1	326	925				1	312	972			
Effingham:																		
September				6	307	959	5	311	953									
October							3	319	921									
November				8	301	1,007	12	314	988				1	337	988			
December				1	295	1,016	7	308	1,010									
January				2	290	1,035	6	314	1,007									
Average	51	316	989	17	298	1,004	33	313	976				1	337	988			
Elbert:																		
September				17	296	969	14	323	928	22	332	874	16	329	972	11	330	960
October				11	317	966	14	314	883	15	335	880	14	313	941	17	300	966
November				14	319	972	15	315	893	6	328	890	5	307	978	11	317	950
December				10	304	947	1	342	830	7	317	883	3	309	969	4	319	909
January				4	306	928	3	302	865				4	333	982	10	314	934
Average	248	318	926	56	308	956	47	319	880	50	328	882	42	318	968	53	316	944

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Emanuel:																		
September				52	303	918	14	323	950	32	335	883	32	329	931	24	340	884
October				6	311	947	20	313	963	7	318	890	24	322	937	29	343	893
November				27	302	972	18	314	985	11	317	921	2	324	991	9	342	909
December				14	291	982	15	316	966	5	325	922	1	324	978	12	334	915
January				8	296	982	9	309	982	2	331	972				17	333	893
Average	390	321	941	107	301	960	76	315	969	57	325	918	59	325	959	91	338	899
Evans:																		
September				15	291	925				1	332	915						
October				4	302	979												
November				9	313	1,029	4	337	1,026				2	348	1,036			
December				2	288	988	4	342	991									
January				1	287	998	1	342	1,007									
Average	43	329	986	31	296	984	9	340	1,008	1	332	915	2	348	1,036			
Fannin:																		
September										1	330	931						
November							3	324	950									
December										3	314	922						
Average	7	323	939				3	324	950	4	322	927						
Fayette:																		
September				4	285	940	1	281	934	5	340	839	3	349	963	3	344	956
October				6	303	950	1	317	871	4	326	846	3	320	871			
November				2	304	890	5	323	915	2	330	858	1	308	912			
December				1	313	934				1	314	883				3	309	877
January				2	333	972	1	303	877	5	318	884	1	320	1,007			
Average	54	318	911	15	308	937	8	306	899	17	326	862	8	324	938	6	327	917

Floyd:																		
September				8	293	994				2	347	846	1	319	928	1	295	1,017
October				21	303	1,007	3	313	940				1	330	931			
November				3	318	1,020	1	324	864							3	331	925
December				2	285	941	1	307	855	1	335	890						
January				1	295	972	3	298	846									
Average	52	318	926	35	299	987	8	311	876	3	341	868	2	325	930	4	313	971
Franklin:																		
September				17	293	915	4	314	903	6	325	846	6	333	921			
October				17	311	947	6	307	890	5	324	861	5	312	950	1	295	937
November				32	313	934	6	326	845	10	323	884	4	331	969			
December				18	302	960	4	304	826	2	317	893	1	333	966	1	306	906
January				11	294	909	1	290	804	6	317	884	1	296	940			
Average	164	311	906	95	303	933	21	308	854	29	321	874	17	321	949	2	301	922
Fulton:																		
September				2	310	991				2	311	830	1	308	887			
October				7	312	950	2	347	975				1	314	906			
November				2	327	979	1	346	877	3	333	899	1	316	915			
December				2	301	963	1	309	852	1	311	902				1	341	896
January				6	313	972										1	327	937
Average	34	322	914	19	313	971	4	334	901	6	318	877	3	313	903	2	334	917
Gilmer:																		
September				1	325	985												
Average	1	325	985	1	325	985												
Glascock:																		
September				3	307	940	1	337	953				1	341	994			
October				3	295	909							1	307	941			
November				1	292	940	2	323	960				1	333	1,064			
December							1	317	1,023				1	331	966			
January				1	326	956												
Average	16	320	969	8	305	936	4	326	979				4	328	991			
Glynn:																		
January							1	262	1,073									
Average	1	262	1,073				1	262	1,073									
Gordon:																		
September										1	369	880	3	321	925	1	334	1,020
October				6	320	1,035				1	336	868	5	334	940			
November				6	326	994	3	319	884	4	339	899				3	315	918
December				5	302	966	2	331	883	12	333	903	1	305	896			
January				4	307	956	1	285	912	3	315	880	1	322	861			
Average	62	322	928	21	314	988	6	312	893	21	338	886	10	321	906	4	325	969

TABLE VI.—*Yields o oil and meal, by countics, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Grady:																		
September				2	296	1,105				2	327	931	1	298	1,039			
October																1	332	953
November				2	294	1,058							1	297	1,051			
December				2	301	1,077												
Average	11	314	1,002	6	297	1,080				2	327	931	2	298	1,045	1	332	953
Greene:																		
September				11	311	934	3	318	925	18	330	842	14	324	928			
October				15	312	941	3	327	953	6	325	852	17	327	982			
November				20	314	950	3	325	909	1	317	861	4	316	963	7	325	931
December				4	329	978	2	325	934	2	329	896	2	307	979	9	315	909
January				5	314	953	3	325	944	2	330	915				10	324	912
Average	161	321	928	55	316	951	14	324	933	29	326	873	37	317	951	26	323	934
Gwinnett:																		
September				1	316	1,029				3	349	836	2	339	979			
October				30	331	934	11	330	887	11	342	846	2	320	912	1	335	912
November				24	322	934	13	327	884	8	331	887	5	331	941	3	331	934
December				11	309	937	3	331	880	10	329	877	2	333	918	3	304	880
January				8	309	947	5	312	868	6	324	896				1	329	909
Average	163	327	910	74	318	956	32	325	880	38	335	868	11	331	938	8	325	909
Habersham:																		
October				1	307	1,001												
November				4	318	912	1	360	921									
December										1	322	903						
January				3	319	925												
Average	10	332	923	8	315	946	1	360	921	1	322	903						

Hall:																		
September							1	315	909	1	351	849	1	317	1,036	1	332	963
October				7	331	956	5	332	915	8	342	864	8	319	969	1	357	994
November				23	325	956	8	320	909	10	332	912	4	330	925	1	319	937
December				5	306	931	6	315	915	8	324	884	2	333	947	2	327	915
January				10	308	931	5	289	849	2	309	864				1	327	947
Average	120	324	928	45	318	944	25	314	899	29	332	875	15	325	969	6	332	951
Hancock:																		
September				20	298	865	4	311	922	39	336	861	61	325	934	48	329	903
October				27	314	902				18	335	871	42	320	940	23	329	890
November				17	308	909				13	329	899	3	322	998	30	322	903
December				8	308	953				18	323	902	1	325	947	35	326	896
January				8	313	934				2	333	896	1	324	1,042	25	326	893
Average	443	320	918	80	308	913	4	311	922	90	331	886	108	323	972	161	326	897
Haralson:																		
October				1	298	1,020				1	333	893				2	318	883
November				4	331	921				2	332	890						
December										1	329	884						
January				1	348	1,017												
Average	12	325	919	6	326	986				4	331	889				2	318	883
Harris:																		
September				3	302	938	1	339	845	8	338	846	7	328	918			
October				13	306	940	2	333	915	11	336	880	14	318	947	1	321	906
November				4	305	969	4	319	906	8	333	899				5	311	956
December				3	320	1,016	3	313	925	6	323	896	2	321	931	4	318	937
January				4	300	979	1	338	899	1	326	953				5	316	922
Average	110	321	925	27	307	968	11	328	898	34	331	895	23	322	932	15	317	930
Hart:																		
September				1	288	925	2	329	899	4	329	883	5	342	921	3	330	960
October				1	311	1,035	8	317	884	4	327	890	11	329	921	5	302	940
November				4	312	1,013	4	324	902	4	330	899	1	311	963	6	313	928
December				6	296	959				4	319	893	1	328	871	4	314	922
January				5	319	969	2	304	836	2	321	842				6	305	915
Average	93	318	919	17	305	980	16	319	880	18	325	881	18	328	919	24	313	933
Heard:																		
October										1	342	975	1	297	1,055			
Average	2	320	1,015							1	342	975	1	297	1,055			
Henry:																		
September				9	300	922	5	318	893	4	328	883	10	339	909	7	337	994
October				17	312	950	4	332	902	4	334	861	6	330	899	9	325	921
November				25	308	937	12	321	890	6	334	858	6	337	944	2	339	944
December				15	305	925	2	314	868	1	337	846				2	338	934
January				4	300	925	3	275	934	4	322	839				1	337	959
Average	158	324	911	70	305	932	26	312	897	19	331	857	22	335	917	21	335	950

TABLE VI.—*Yields of oil and meal, by counties, as compiled by analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Houston:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				10	302	937	2	359	966	8	341	906	5	330	1,013	9	336	906
October				11	300	985	3	308	880	2	342	871	4	328	1,010	16	339	931
November				8	305	997				5	328	874	1	350	988	15	335	903
December				5	309	1,036	1	316	1,010	7	326	902	1	357	966	7	336	928
January				8	294	1,001	1	326	1,016	1	309	966				5	328	928
Average	135	327	955	42	302	991	7	327	968	23	329	904	11	341	994	52	335	919
Irwin:																		
September				3	324	1,017	6	315	950	1	325	906	2	293	931	2	318	915
October				1	307	982	1	289	994							1	315	849
Average	17	311	938	4	316	1,000	7	302	972	1	325	906	2	293	931	3	317	882
Jackson:																		
September				11	295	903	3	319	909	2	334	880	6	312	937	3	340	871
October				10	308	903	13	315	921	2	351	883	11	314	931	6	327	950
November				17	323	912	10	322	890	2	315	909	6	302	978	3	320	934
December				7	298	918	4	315	925	5	307	909	1	288	966			
January				5	304	918	2	283	941				2	307	950	1	331	902
Average	132	316	918	50	306	911	32	311	917	11	327	895	26	305	952	13	330	914
Jasper:																		
September				1	303	1,026	15	335	906	16	336	852	24	320	941	5	332	925
October				27	333	941	3	327	918	7	345	865	18	315	960	7	331	947
November				26	327	959	1	304	994	4	327	896	6	298	988			
December				10	324	959	1	329	896	2	321	874				4	333	909
January				8	320	960				1	319	918				4	330	884
Average	190	324	932	72	321	969	20	324	929	30	330	881	48	311	963	20	332	916

Jeff Davis:																		
September				38	309	940	3	293	1,029	1	326	902	4	327	960			
October				3	299	998										1	310	921
November				1	283	1,017	1	288	915									
December				1	308	1,010												
January										2	313	921						
Average	55	310	951	43	300	991	4	291	972	3	320	912	4	327	960	1	310	921
Jefferson:																		
September				15	311	1,051	3	314	1,001	2	338	903	14	329	975	7	349	912
October				7	317	960	9	314	966	1	342		3	339	966	9	330	906
November				9	309	966	7	313	1,016	6	331	953	1	353	975	11	325	922
December				5	314	979	24	319	982	4	322	918	2	324	1,004	6	318	909
January				12	310	985	2	317	978	1	325	899	1	309	956	5	326	931
Average	166	324	957	48	312	988	45	315	989	14	332	918	21	331	975	38	330	916
Jenkins:																		
September				18	310	944	6	308	979	6	351	883	10	335	931	18	347	922
October				4	305	972	2	333	953	10	341	864	16	330	940	15	343	918
November				16	300	982	12	307	994	12	341	928				14	340	912
December				14	296	985	4	302	988	19	333	944				19	336	928
January				5	291	1,036				1	318	928				26	339	931
Average	247	325	946	57	300	984	24	313	979	48	337	909	26	333	936	92	341	922
Johnson:																		
September				11	313	896	4	314	893				4	323	941	4	335	902
October				1	335	937	6	314	959	3	331	884				3	334	890
November				2	322	998	2	320	941	3	328	887	1	345	909	1	329	903
December				1	312	982	1	318	947									
January				4	312	972	2	301	1,029				1	318	972			
Average	54	325	927	19	319	957	15	313	954	6	330	886	6	329	941	8	333	898
Jones:																		
September				3	310	937	2	329	890	10	348	842	9	330	988	3	333	915
October				3	344	966	5	334	941	10	344	864	11	324	960	4	333	890
November				4	333	931				2	341	893	1	303	1,007	3	333	906
December				2	317	963				3	333	909				3	333	915
January				2	336	931	1	333	902							1	314	969
Average	82	330	928	14	328	946	8	332	911	25	342	877	21	319	985	14	329	919
Laurens:																		
September				39	310	960	9	314	941	7	338	909	28	321	988	11	347	944
October				20	319	972	1	307	921	3	327	906	7	329	982	8	351	925
November				21	304	969	4	311	972	2	335	912	3	336	956	5	339	931
December				9	314	994	2	315	953	14	318	899	2	323	998	2	345	915
January				9	305	979	2	329	959							7	330	915
Average	215	325	948	98	310	975	18	315	949	26	330	907	40	327	981	33	342	926

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Lee:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				6	309	940	7	320	959	4	352	887	15	327	1,007	14	336	978
October				4	299	918	8	331	956	17	344	922	8	319	1,007	8	341	950
November				4	310	1,017	1	340	944	3	337	941				9	344	950
December				4	316	1,017				1	336	934				4	331	941
January				1	296	922	2	328	998									
Average	120	328	962	19	306	963	18	330	964	25	342	921	23	323	1,007	35	338	955
Liberty:																		
September				3	291	956	1	327	950	2	310	874						
October							2	292	940									
November				3	290	1,042	2	311	1,001									
December							5	326	1,001									
Average	18	305	949	6	291	999	10	314	973	2	310	874						
Lincoln:																		
September				5	281	941							7	345	1,036			
November				3	295	975												
January				3	295	1,061										1	298	902
Average	19	311	977	11	290	992							7	345	1,036	1	298	902
Lowndes:																		
September				3	311	959	7	338	1,042	3	352	925				3	364	963
October				3	308	1,013				1	390	950	2	374	1,010	6	340	909
November				3	309	1,016	1	345	1,001				1	333	1,058	2	341	941
December				3	295	997	2	340	1,131				5	351	1,042	14	356	934
January							1	314	868				1	354	1,048	2	347	902
Average	63	343	983	12	306	996	11	334	1,011	4	371	938	9	353	1,040	27	350	930

Lumpkin:																		
September																1	352	846
November																1	295	956
Average	2	324	901													2	324	901
McDuffie:																		
September				6	297	978	3	309	972	3	332	849	13	320	947	7	327	915
October				9	306	931	4	310	937	1	327	874	17	322	931	6	318	868
November				9	306	960	6	316	950	4	320	874	2	324	960	13	326	915
December				4	321	1,032	1	316	982	2	321	883	1	299	972	10	327	890
January				8	317	963	2	331	928	1	324	918	3	305	960	3	317	909
Average	138	317	932	36	309	973	16	316	954	11	325	880	36	314	954	39	323	899
McIntosh:																		
September							1	315	975				2	294	1,036	1	332	912
October							1	308	950							2	314	909
November							3	302	880									
January																1	332	902
Average	11	309	960				5	308	935				2	294	1,036	4	326	908
Macon:																		
September				2	309	985	7	324	950	5	327	890	8	321	991	6	334	925
October				4	302	941	3	310	928	1	336	915				3	347	868
November				7	309	966	1	291	896									
December				8	309	972	1	319	966	1	320	906				4	334	918
January				5	301	1,007	4	317	969									
Average	70	321	943	26	306	974	16	312	942	7	328	904	8	321	991	13	338	904
Madison:																		
September				4	286	941	1	342	896	2	363	883	2	317	899	1	315	931
October				3	303	982	2	326	871	8	327	877	5	315	893			
November				3	303	883	5	320	921	2	327	937						
December				3	297	991	1	302	880	7	317	909						
January							3	307	912							1	311	975
Average	53	316	919	13	297	949	12	319	896	19	334	902	7	316	896	2	313	953
Marion:																		
September				2	314	975	9	327	896	3	342	868	3	316	953			
October				4	299	941	8	325	941				9	317	988	2	322	931
November				2	307	922	4	318	918	4	333	928	1	330	956	4	330	915
December							2	321	941							4	328	921
January				2	284	975	1	317	969							4	327	912
Average	68	322	934	10	301	954	24	322	933	7	338	898	13	321	966	14	327	920

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Meriwether:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				10	308	937	9	325	865	16	341	845	27	330	921	7	330	903
October				10	311	944	8	322	880	4	335	845	17	328	909	7	315	921
November				10	318	928	3	316	868	6	333	861	3	338	960	9	324	925
December				4	306	890				3	309	865	1	302	960	6	318	953
January				4	317	947	3	317	880	2	331	852				6	334	921
Average	175	322	904	38	312	929	23	320	873	31	330	854	48	325	938	35	324	925
Miller:																		
September							1	280	991	2	333	906	3	281	1,093	1	322	994
October													4	291	1,036			
November				3	300	1,042												
Average	14	304	1,000	3	300	1,042	1	280	991	2	333	906	7	286	1,065	1	322	994
Milton:																		
January				1	307	1,007												
Average	1	307	1,007	1	307	1,007												
Mitchell:																		
September				6	292	979	4	317	1,067	2	332	909	7	307	1,042	2	333	994
October				5	295	1,026	2	292	969	2	350	928						
November				3	295	1,048	2	324	998									
December				2	275	1,029	1	271	997									
January							4	304	997									
Average	42	314	996	16	289	1,021	13	302	1,006	4	341	919	7	307	1,042	2	333	994

Monroe:																		
September	.....	.....	.....	7	310	998	4	322	915	9	334	861	8	327	972	6	343	985
October	.....	.....	.....	20	303	950	4	326	912	8	331	877	3	321	963	5	329	969
November	.....	.....	.....	5	297	944	3	333	890	.....	.....	.....	3	318	975	6	329	944
December	.....	.....	.....	4	306	950	.....	.....	.....	6	318	899	3	317	1,032	3	310	997
January	.....	.....	.....	3	293	963	5	312	947	1	328	877	.....	.....	.....	.....	.....	.....
Average	116	320	943	39	302	961	16	323	916	24	328	879	17	321	986	20	328	974
Montgomery:																		
September	.....	.....	.....	23	305	947	21	314	944	3	324	883	16	325	963	4	319	972
October	.....	.....	.....	12	308	953	6	305	934	2	327	868	1	319	944	4	336	950
November	.....	.....	.....	15	306	994	7	310	953	.....	.....	.....	2	320	975	.....	.....	.....
December	.....	.....	.....	10	311	985	4	299	982	3	342	978	.....	.....	.....	3	314	893
January	.....	.....	.....	10	296	982	.....	.....	.....	1	329	959	.....	.....	.....	15	333	937
Average	162	318	949	70	305	972	38	307	953	9	331	922	19	321	961	26	326	938
Morgan:																		
September	.....	.....	.....	25	299	921	20	318	902	26	333	852	19	322	941	9	329	890
October	.....	.....	.....	16	319	934	14	314	902	18	335	871	28	308	937	25	314	912
November	.....	.....	.....	25	324	934	10	317	899	6	317	906	.....	.....	.....	5	323	903
December	.....	.....	.....	10	306	909	4	332	918	10	319	806	.....	.....	.....	4	319	941
January	.....	.....	.....	18	314	937	1	317	864	5	319	877	.....	.....	.....	2	313	871
Average	300	318	909	94	312	927	49	320	897	65	325	880	47	315	939	45	320	903
Murray:																		
October	.....	.....	.....	1	319	941	.....	.....	.....	3	333	903	.....	.....	.....	.....	.....	.....
November	.....	.....	.....	3	326	988	1	320	864	.....	.....	.....	.....	.....	.....	3	326	909
December	.....	.....	.....	4	302	937	.....	.....	.....	3	314	925	.....	.....	.....	1	318	880
January	.....	.....	.....	5	304	953	.....	.....	.....	1	338	880	.....	.....	.....	.....	.....	.....
Average	25	321	904	13	313	955	1	320	864	7	328	903	.....	.....	.....	4	322	895
Muscogee:																		
September	.....	.....	.....	22	295	944	20	319	947	16	334	864	32	315	960	1	303	937
October	.....	.....	.....	23	292	972	19	322	925	5	335	871	9	325	950	3	322	988
November	.....	.....	.....	18	295	998	23	315	941	16	324	922	.....	.....	.....	3	308	982
December	.....	.....	.....	11	290	998	16	318	931	16	328	928	.....	.....	.....	4	298	947
January	.....	.....	.....	3	307	985	.....	.....	.....	2	339	912	.....	.....	.....	2	316	950
Average	264	315	946	77	296	979	78	319	936	55	332	899	41	320	955	13	309	961
Newton:																		
September	.....	.....	.....	5	315	937	13	324	937	14	335	830	14	323	922	7	329	941
October	.....	.....	.....	15	322	944	11	320	902	15	333	827	19	313	912	8	321	915
November	.....	.....	.....	24	324	928	13	318	899	7	329	871	1	312	921	1	321	922
December	.....	.....	.....	11	310	934	3	317	909	4	318	909	2	318	906	4	303	903
January	.....	.....	.....	15	321	947	5	309	909	3	305	852	1	295	975	5	323	925
Average	220	318	910	70	318	938	45	318	911	43	324	858	37	312	927	25	319	921

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Oconee:																		
September				5	311	940	2	328	941	6	330	849	4	323	928	5	336	934
October				4	315	966	4	332	950	5	342	858	4	347	941	6	312	928
November				9	308	934	6	314	902	2	324	925	2	328	1,010			
December				6	303	1,023	2	318	865	3	331	903	1	337	1,004			
January				1	312	915	1	316	896									
Average	78	324	931	25	310	956	15	322	911	16	332	884	11	334	971	11	324	931
Oglethorpe:																		
September				2	298	928				2	339	845	3	328	925	2	334	864
October				8	325	877	7	322	931	5	344	868	4	331	925	4	314	903
November				28	316	912	4	318	902	1	342	941	2	312	972	2	318	903
December				5	308	947	3	311	925	2	335	861				1	307	890
January				8	318	947	5	318	912							2	331	918
Average	100	323	911	51	313	922	19	317	918	10	340	879	9	324	941	11	321	896
Paulding:																		
September										1	349	808						
October				7	319	941				1	338	845				1	331	906
November				3	311	890	2	325	934									
December				2	325	940	2	303	899	1	338	884				2	325	959
January				3	301	960												
Average	25	325	907	15	314	933	4	314	917	3	342	846				3	328	933
Pickens:																		
October				1	337	1,150												
November							1	336	963	2	333	960				1	320	934
December							1	342	956	1	332	922						
January				1	317	912												
Average	8	350	967	2	327	1,031	2	339	960	3	333	941				1	320	934

Pierce:																		
September							3	333	979	1	359	1,064	2	317	906			
October				2	320	994	3	337	1,074									
November				6	298	1,061	6	340	1,054									
December							10	333	1,073									
January				1	310	1,149										1	346	982
Average	35	333	1,013	9	309	1,068	22	336	1,045	1	359	1,064	2	317	906	1	346	982
Pike:																		
September				12	286	966	10	323	918	20	332	849	15	322	922	12	333	947
October				25	306	937	9	318	915	15	330	858	14	323	944	5	313	925
November				20	311	941	12	316	906	3	317	921				11	315	966
December				9	293	937	8	310	912	5	327	896	6	314	947	5	322	944
January				9	282	950				8	323	883				8	313	944
Average	241	316	925	75	296	946	39	317	913	51	326	881	35	320	938	41	319	945
Polk:																		
September				3	269	985	2	295	884	3	332	830	2	335	928	3	301	883
October				14	294	998				2	347	887	2	338	953	4	322	906
November				8	311	1,023	2	314	883	3	328	883				2	317	944
December				10	286	969	3	296	842	7	317	899				2	316	884
January				1	302	864	2	305	864	1	323	909				1	351	959
Average	77	316	915	36	292	968	9	303	868	16	329	882	4	337	941	12	321	915
Pulaski:																		
September				2	305	922	6	335	918	8	332	839	16	318	994	5	345	918
October				1	294	896	3	338	903	3	341	868	5	311	956	14	339	906
November				2	299	982				3	322	877	2	330	963	11	331	893
December				4	303	985	2	335	953	1	316	941	1	309	997	9	333	934
January				3	292	1,001	2	340	975							2	314	874
Average	105	323	932	12	299	957	13	337	937	15	328	881	24	317	978	41	332	905
Putnam:																		
September				8	314	912	9	328	899				8	334	959	2	346	953
October				7	327	944	20	323	890	9	340	871	4	312	941	7	331	921
November				21	328	944	1	325	937	5	332	899	9	303	959	2	329	890
December				5	321	934	2	309	903	2	318	909				1	312	934
January				13	329	940	1	308	896									
Average	136	324	922	54	324	935	33	319	905	16	330	893	2	316	953	12	330	925
Quitman:																		
September													1	340	979			
October													1	333	959			
November										1	352	934						
January													2	314	918			
Average	5	341	943							1	352	934	4	329	952			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Rabun:																		
September																1	342	1,073
October							4	332	950							1	352	950
November				1	307	915												
December							1	310	937									
Average	8	325	957	1	307	915	5	321	944							2	347	1,012
Randolph:																		
September				6	309	978	5	321	982	6	340	887	6	334	988	8	346	959
October				4	301	985	8	326	941	17	338	931	10	324	991	10	332	912
November				6	308	985	2	324	991				2	332	1,064	2	328	953
December				2	290	997	2	336	975				1	367	1,036	1	337	1,004
January				1	275	944	1	315	1,004							2	308	1,010
Average	102	326	971	19	297	978	18	324	979	23	339	909	19	339	1,019	23	330	968
Richmond:																		
September				27	294	997	6	311	988	14	340	902	33	334	982	21	344	944
October				23	304	1,029	6	319	963	13	327	959	20	323	972	12	327	937
November				19	307	1,029	10	316	994	9	316	985	8	314	1,010	11	331	941
December				9	299	1,039	4	310	1,013	6	306	960	4	329	1,016	2	324	912
January				7	303	1,017	1	297	972	1	306	975				3	321	940
Average	269	317	979	85	301	1,022	27	311	986	43	319	956	65	325	995	49	329	935
Rockdale:																		
October				5	321	953	1	319	928	2	340	874	1	333	931			
November				1	326	928	2	334	902									
December				2	328	969	1	297	868	2	331	909				1	356	928
January				2	329	988	2	309	874									
Average	22	333	921	10	326	960	6	315	893	4	336	892	1	333	931	1	356	928

Schley:																		
September							1	348	934	2	341	871	1	317	940			
October				1	307	1,017												
November				3	304	972				2	322	921						
December										4	333	925						
January				1	329	960												
Average	15	328	941	5	313	983	1	348	934	8	332	906	1	317	940			
Screven:																		
September				52	309	944	11	318	922	3	351	880				3	351	903
October				6	305	931	12	316	941	1	335	928	3	334	921	2	345	874
November				13	307	997	47	318	953	11	334	902	2	331	953	3	360	912
December				4	291	1,054	18	309	988	2	347	947				12	342	903
January				13	303	988	25	316	953	2	335	909				2	348	899
Average	247	328	936	88	303	983	113	315	951	19	340	913	5	333	937	22	349	898
Spalding:																		
September				5	313	978	1	316	1,058	6	339	887	3	314	925	2	330	1,016
October				12	295	972				4	337	839				1	320	940
November				14	303	985	1	282	994	1	323	915						
December				1	297	1,054	1	329	953	2	317	877	1	295	1,010	3	339	953
January				3	287	972				1	308	893	2	306	972			
Average	64	314	963	35	299	992	3	309	1,002	14	325	882	6	305	969	6	330	970
Stephens:																		
September				1	313	903	1	314	1,077	3	315	842	2	351	928	1	296	1,020
October				2	310	896	7	326	830	1	335	830	5	324	918			
November				7	320	909	6	303	902	1	328	906	1	303	896			
December				2	307	963	6	297	868	3	313	865	1	313	969			
January				1	303	883	2	278	925	1	337	880						
Average	54	312	929	13	311	911	22	304	920	9	326	865	9	323	928	1	296	1,020
Stewart:																		
September				8	315	972	1	336	928	10	352	890	8	330	997	5	334	940
October				2	306	1,023	2	333	982	18	338	921	8	318	991	4	330	921
November				1	346	960				5	323	918				8	323	941
December							2	329	937	4	328	918				4	326	1,001
January																3	318	944
Average	93	328	958	11	322	985	5	333	949	37	335	912	16	324	994	24	326	949
Sumter:																		
September				4	311	947	7	324	956	9	341	918	21	321	1,001	15	349	918
October				7	324	953	10	326	922	17	337	918	10	330	997	17	338	912
November				3	343	969	3	318	921	2	341	959				9	335	953
December							5	314	934							12	336	937
January							1	313	950				1	319	1,017	10	330	960
Average	163	329	953	14	326	956	26	319	937	28	340	932	32	323	1,005	63	338	936

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Talbot:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September							6	333	925	8	334	871	7	323	966	5	318	928
October				7	295	979	6	314	918	9	331	884	7	317	969	6	313	921
November				1	286	928	2	321	918	3	329	890				2	332	950
December				2	300	1,001	1	298	921	4	314	928				3	323	937
January				4	294	1,016												
Average	83	316	939	14	294	981	15	317	921	24	327	893	14	320	968	16	322	934
Taliaferro:																		
September				4	303	956	4	320	922	16	337	849	10	327	896	6	325	960
October				3	313	890	4	317	896	9	333	839	33	325	922	5	321	865
November				12	312	931	2	314	915	1	334	918	1	318	931	9	320	921
December				5	295	985				1	312	852	3	316	960	8	327	896
January				6	293	963	1	339	918				1	323	963	4	338	884
Average	148	321	912	30	303	945	11	323	913	27	329	865	48	322	934	32	326	905
Tattnall:																		
September				14	286	959	9	314	918	1	321	858	1	330	959	1	371	921
October				11	336	1,045	11	331	975	3	350	906	1	348	950	1	354	978
November				22	320	1,083	13	321	960	1	331	941				1	384	1,023
December				5	313	1,127	7	308	1,020				3	333	1,004	2	333	931
January				3	294	972	4	326	1,023							6	326	925
Average	120	331	969	55	310	1,037	44	320	979	5	334	902	5	337	971	11	354	956
Taylor:																		
September				3	310	991	11	325	928	4	340	874	5	324	978	2	334	959
October				12	307	1,001	2	315	902	8	334	890	5	319	982	6	333	921
November				6	302	978	6	312	950	5	321	896				8	324	896
December				1	288	1,016				3	323	937	1	314	994	5	320	963
January				2	291	1,023										5	330	956
Average	100	319	950	24	300	1,002	19	317	927	20	330	899	11	319	985	26	328	939

Telfair:																		
September				23	300	953	12	297	988	4	321	874	21	317	956	30	328	928
October				14	296	978	1	313	966	8	336	902	3	301	978	24	325	921
November				19	304	1,010	9	309	979	4	319	925	1	331	1,067			
December				5	295	1,004										19	323	934
January				1	293	1,026				1	337	941				23	323	937
Average	222	315	963	62	298	994	22	306	978	17	328	911	25	316	1,000	96	325	930
Terrell:																		
September				4	311	956	19	333	963	41	345	896	18	327	1,007	15	338	934
October				16	313	988	2	330	1,016	46	343	944	5	326	1,013	14	323	921
November				5	325	988	1	327	960	29	337	940	1	318	1,048	3	328	941
December				4	308	997	2	319	963	2	327	934						
January				2	327	972	1	323	944	1	341	972				2	330	956
Average	233	327	969	31	317	980	25	326	969	119	339	937	24	324	1,023	34	330	938
Thomas:																		
September				5	307	997	4	317	969	3	347	893	10	318	1,029	3	345	975
October				2	311	1,032				1	313	947	5	315	998	1	326	922
November				1	291	1,001												
December				1	300	1,013										1	354	944
January				2	280	1,045												
Average	39	321	974	11	298	1,018	4	317	969	4	330	920	15	317	1,014	5	342	947
Tift:																		
September				16	302	1,010	13	303	1,001	6	325	953	22	312	997	2	325	953
October				1	295	972	4	302	969	4	327	934	6	309	1,020			
November				2	302	1,023	1	334	1,016	1	323	982				1	367	950
December										5	329	953				3	352	966
Average	87	320	984	19	300	1,002	18	313	995	16	326	956	28	311	1,009	6	348	956
Toombs:																		
September				2	297	937							1	326	944	1	364	982
October				1	316	1,023	5	319	966				2	331	941	1	353	1,017
November				4	303	975	22	311	963				1	352	978			
December							4	298	988				1	310	966	1	365	953
January				3	311	998	7	315	947									
Average	56	327	973	10	307	983	38	311	966				5	330	957	3	361	984
Troup:																		
September				11	292	918	1	303	865	4	320	826	17	312	902	5	321	922
October				3	314	963	14	321	877	4	323	868	4	323	931	6	324	947
November				7	317	950	10	323	934	3	322	912	1	319	940	3	315	912
December				5	321	928	6	322	959	12	324	899	1	314	874	1	346	960
January				3	323	950	2	298	858	6	313	934				3	312	944
Average	132	318	916	29	313	942	33	313	899	29	320	888	23	317	912	18	324	937

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Turner:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				15	299	937	24	300	959	6	330	887	37	313	966	8	331	922
October				4	291	1,017	8	303	922				2	291	969	5	322	896
November				1	313	960	1	333	940	2	309	931	1	311	1,004	14	324	909
December				1	285	998	1	354	1,029	28	321	915				7	324	915
January																10	322	909
Average	175	314	948	21	297	978	34	323	963	36	320	911	40	305	980	44	325	910
Twiggs:																		
September				10	319	934				14	339	855	9	328	979	5	339	937
October				13	308	937				8	330	921	10	326	959	10	330	899
November				17	307	959				6	323	877	1	321	1,017	3	334	896
December				4	297	1,001				4	328	884				2	338	887
January				14	301	969	3	335	934	1	319	963				2	328	871
Average	136	326	935	58	306	960	3	335	934	33	328	900	20	325	985	22	334	898
Upson:																		
September							5	332	899	11	333	839	6	314	918	4	340	941
October				1	328	1,092	4	315	846	4	333	855	2	318	950	1	300	1,023
November				2	295	963	2	335	1,013	1	314	842				1	315	918
December				1	311	969	1	316	988	1	315	893	1	314	991	3	324	906
January				1	274	925	1	333	947	3	326	909						
Average	56	317	939	5	302	987	13	326	939	20	324	868	9	315	953	9	320	947
Walker:																		
October				4	304	1,036				1	315	880				1	333	903
November				1	310	975	1	297	1,096				1	314	960			
December				1	313	1,051							1	321	1,042	1	312	887
January							1	306	1,042									
Average	13	313	973	6	309	1,021	2	302	1,069	1	315	880	2	318	1,001	2	323	895

Walton:																		
September				5	295	953	8	328	921	7	337	846	2	307	903	3	327	880
October				4	298	979	8	326	890	4	336	871	8	322	890	2	315	842
November				13	308	963	15	331	899	4	327	887	4	321	937	4	312	890
December				5	316	931	18	290	855	6	325	868	2	324	921	1	298	902
January				8	304	947	2	325	937	3	322	845				2	336	902
Average	138	318	903	35	304	955	51	320	900	24	329	863	16	319	913	12	318	883
Ware:																		
September				6	297	985	4	284	998	1	319	925	1	311	959			
October				4	323	997	5	301	1,007									
November				8	305	998	3	336	1,055							2	333	912
December				1	296	979	2	342	1,054				1	315	988	1	369	969
January				5	288	972	1	296	959									
Average	45	319	968	24	302	986	15	312	1,015	1	319	925	2	313	974	3	351	941
Warren:																		
September				4	291	858				15	335	842	25	336	884	28	333	877
October				5	321	934				5	330	855	12	320	925	17	335	883
November				1	308	868				5	336	877				9	333	884
December										25	326	887	2	310	956	6	328	868
January				3	312	953				1	331	849	2	336	969	7	332	864
Average	172	325	894	13	308	903				51	332	862	41	326	934	67	332	875
Washington:																		
September				8	318	912	3	326	991	7	350	880	4	350	978	2	340	1,007
October				2	323	915	10	315	960	4	346	896	3	318	931	3	345	918
November				6	326	956	4	312	1,007	1	333	922	3	331	975			
December				11	325	956							1	337	1,042			
January				6	314	960	1	317	918				1	347	979			
Average	80	332	950	33	321	940	18	318	969	12	343	899	12	337	981	5	343	963
Wayne:																		
September				5	293	1,004				1	316	842	3	332	975	2	334	921
October				1	270	1,001	1	358	1,083	1	329	918	1	315	994			
November				10	305	1,051	6	321	1,020				1	344	1,032			
December				3	291	1,016	1	358	1,074				3	317	991	3	333	937
January				2	299	1,058	1	331	982	1	332	944	1	342	1,051	3	313	909
Average	50	323	980	21	292	1,026	9	342	1,040	3	326	901	9	330	1,009	8	327	922
Webster:																		
September				2	305	966				4	355	899	3	329	1,016	1	335	909
October							2	335	893	3	333	931						
November							1	311	944	1	317	915						
December				1	326	991				3	331	903						
January										1	324	963				3	338	921
Average	25	327	950	3	316	979	3	323	919	12	332	922	3	329	1,016	4	337	915

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

GEORGIA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Wheeler:																		
September				18	303	950	7	316	956	5	342	887	21	327	922	6	337	950
October				3	316	1,016				3	327	896	3	313	928	6	331	925
November				1	307	1,017	1	337	934				1	316	959			
December				4	298	979				1	319	896				8	332	947
January				2	316	959										9	327	915
Average	99	323	938	28	308	984	8	327	945	9	329	893	25	319	936	29	332	934
White:																		
November													1	340	991			
January										1	329	887						
Average	2	335	939							1	329	887	1	340	991			
Whitfield:																		
October				2	312	1,105				1	358	883	3	338	975			
November				4	310	1,064												
December							1	293	931									
January				1	349	994												
Average	12	328	961	7	324	1,054	1	293	931	1	358	883	3	338	975			
Wilcox:																		
September				20	295	921	26	312	937	11	333	893	26	309	991	19	337	928
October				14	294	978	12	304	928	5	331	899	3	302	1,017	13	328	922
November				8	298	1,017	3	328	928	7	321	925	1	297	1,020	13	324	941
December				2	304	1,032	2	319	969	33	331	1,001				7	329	915
January							3	306	950	2	314	918				10	326	940
Average	240	314	959	44	298	987	46	314	942	58	326	927	30	303	1,009	62	329	929

Wilkes:																		
September				3	313	925	2	313	925	5	341	864	11	319	947	3	334	937
October				5	314	915	3	308	883	2	334	842	2	315	884	2	316	947
November				9	313	921	1	315	966				2	312	975	3	318	953
December				2	309	972				4	319	912						
January				2	314	950										2	319	947
Average	63	319	923	21	313	937	6	312	925	11	331	873	15	315	935	10	322	946
Wilkinson:																		
September				2	304	997	1	295	941	2	335	887	2	319	941	1	372	988
October				6	293	928				1	352	874	5	325	991	3	316	903
November				7	307	940				1	344	931				3	342	893
December				2	304	985				4	325	887						
January				4	295	972	1	329	890	1	329	934						
Average	46	323	935	21	301	964	2	312	916	9	337	903	7	322	966	7	343	928
Worth:																		
September				14	304	940	15	310	966	8	328	871	19	304	1,004	22	332	925
October				8	303	969	5	299	928	4	333	877	1	333	934	5	324	899
November				3	304	1,010	2	304	975	6	333	899				2	333	915
December				2	295	940	1	310	1,023	6	313	909				11	321	912
January							1	277	947	1	330	960						
Average	136	315	944	27	302	965	24	300	968	25	327	903	20	319	969	40	328	913

KENTUCKY.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	27	303	1,069	8	298	1,094	10	336	917				8	324	1,047	1	303	978
Chester	1	312	1,035	1	312	1,035												
Davies	1	269	1,058	1	269	1,058												
Fulton	24	314	1,014	5	293	1,112	10	336	917				8	324	1,047	1	303	978
Southampton	1	317	1,169	1	317	1,169												

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

KENTUCKY—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Chester:																		
November				1	312	1,035												
Average	1	312	1,035	1	312	1,035												
Davies:																		
September				1	269	1,058												
Average	1	269	1,058	1	269	1,058												
Fulton:																		
September				2	288	1,096	1	340	975				2	349	1,035			
October				3	297	1,127							4	314	1,023			
November							8	341	915				1	345	1,105			
December							1	326	861									
January													1	289	1,026	1	303	978
Average	24	314	1,014	5	293	1,112	10	336	917				8	324	1,047	1	303	978
Southampton:																		
October				1	317	1,169												
Average	1	317	1,169	1	317	1,169												

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

LOUISIANA.

BY PARISHES.

Parish.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	2,104	310	1,041	515	304	1,093	605	312	1,063	550	315	1,005	293	312	1,009	141	310	1,015
Acadia	137	302	1,098	18	271	1,202	54	312	1,095	53	309	1,067	7	307	1,084	5	310	1,042
Ascension	28	307	1,041	2	323	1,077	10	310	1,046	6	303	1,038	2	287	1,036	8	313	1,010
Avoyelles	401	318	1,022	83	308	1,108	132	318	1,069	131	322	994	37	321	966	18	321	1,021
Beauregard	6	309	1,049	4	290	1,099										2	327	998
Bienville	13	308	996	4	311	1,059	2	313	982	1	322	1,007	4	297	1,029	2	299	903
Bossier	84	305	1,114	4	292	1,093	28	310	1,065	17	311	1,035	35	306	961			
Caddo	198	307	1,045	43	292	1,102	39	309	1,057	64	305	1,040	30	314	1,001	22	317	1,027
Calcasieu	8	313	1,035	3	312	1,061	1	296	1,048	3	327	993				1	315	1,036
Caldwell	14	309	1,045	9	294	1,130	2	291	1,108	1	323	978	2	326	965			
Cameron	2	293	1,020										1	323	966	1	262	1,074
Catahoula	3	303	1,024	2	308	1,081							1	296	966			
Claiborne	36	305	998	3	284	1,069	16	317	957	5	296	1,034	11	306	955	1	320	975
Concordia	7	325	1,052	3	326	1,000	1	344	1,073	2		1,067				1	304	1,067
De Soto	53	294	1,038	4	282	1,118	14	293	1,029	20	293	1,029	14	293	958	1	307	1,054
East Baton Rouge	25	294	1,044				11	307	1,090	1	303	922	1	277	1,108	12	290	1,054
East Carroll	3	345	1,003	2	338	960	1	352	1,045									
East Feliciana	22	299	1,043	15	309	1,096	5	306	1,039				2	282	995			
Evangeline	42	309	1,074	9	305	1,124	7	304	1,067	18	319	1,034	8	309	1,071			
Franklin	26	301	1,077	9	300	1,148	3	267	1,130	8	312	1,020	5	314	1,004	1	314	1,083
Grant	38	317	1,043	17	298	1,085	14	320	1,095	3	318	1,018	4	331	972			
Iberia	1	299	1,083										1	299	1,083			
Iberville	13	321	1,008	2	330	1,064	7	301	1,067	4	331	893						
Jackson	3	289	1,088	1	289	1,082				1	287	1,073	1	291	1,108			
Jefferson	4	306	1,031	2	291	1,099							2	320	962			
Jefferson Davis	3	275	1,115				3	275	1,115									

TABLE VI.—*Yields of oil and meal, by counties, as compiled by analyses*—Continued.

LOUISIANA—Continued.

BY PARISHES—Continued.

Parish.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
La Salle	3	302	1,084	1	295	1,102							2	308	1,066			
Lafayette	29	308	1,084	10	298	1,187	7	301	1,082	8	314	1,067	1	301	1,099	3	327	985
Lafourche	3	323	1,006							2	323	1,006						
Lincoln	4	304	1,016	1	305	1,035	1	315	1,086	2	292	928						
Livingston	37	303	1,047	14	306	1,114	11	309	1,129	5	307	977	2	300	987	5	292	1,028
Madison	7	318	1,040	3	316	1,061	2	334	1,035				2	303	1,023			
Morehouse	22	297	1,041	9	287	1,070	8	302	1,060				5	303	994			
Natchitoches	197	309	1,011	29	294	1,099	60	316	1,053	68	313	1,011	36	318	971	4	303	922
Ouachita	33	318	1,025	8	291	1,057	9	316	1,060	4	335	971	6	326	1,048	6	324	988
Pointe Coupee	32	326	1,023	5	318	1,072	10	321	1,029	7	326	997	6	350	976	4	316	1,039
Plaquemines	1	320	1,067	1	320	1,067												
Rapides	167	319	1,059	106	308	1,134	21	323	1,082	23	317	1,017	10	328	1,024	7	321	1,038
Red River	72	305	1,069	4	296	1,150	19	307	1,058	35	305	1,038	14	311	1,029			
Richmond	49	318	1,031	10	303	1,095	5	319	1,040	26	331	986	4	313	1,022	4	324	1,012
Sabine	18	306	1,055	11	313	1,120	3	287	1,092	1	325	997	3	297	1,010			
St. Bernard	1	359	871				1	359	871									
St. Charles	3	322	1,039				1	342	1,108	2	302	970						
St. Landry	92	313	1,047	25	301	1,147	27	324	1,071	21	311	988	2	314	1,036	17	315	993
St. Martin	6	318	1,192	2	333	1,203	4	303	1,181									
St. Tammany	8	307	1,080	6	311	1,050	2	302	1,110									
St. Mary	1	285	1,035				1	285	1,035									
Tangipahoa	3	280	1,021	2	308	1,086				1	251	956						
Tensas	29	331	1,007	2	332	1,001	26	335	1,028	1	327	991						
Union	18	311	1,018	1	297	1,074	2	322	1,021				15	314	958			

Vermilion	7	318	1,038							1	339	1,080				6	297	995
Vernon	2	324	969							1	312	985	1	336	953			
Washington	11	309	1,068	4	313	1,127	7	305	1,009									
Webster	5	315	1,031	1	311	1,118							4	319	944			
West Baton Rouge	3	341	956										3	341	956			
West Carroll	42	314	1,040	14	291	1,110	17	318	1,067	2	328	1,016	6	321	1,036	3	311	972
West Feliciana	22	303	1,036	4	289	1,070	9	313	1,062	1	333	969	1	378	1,039	7	302	1,039
Winn	5	305	1,050				2	295	1,155	1	324	991	2	296	1,005			

By Parishes and Months.

Parish and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Acadia:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				9	281	1,197	7	307	1,080	7	319	1,112	4	289	1,067	2	303	1,121
October							24	297	1,089	7	286	1,070	2	352	1,036	1	305	1,096
November				3	278	1,203	18	307	1,111	17	305	1,035	1	279	1,150	1	314	1,093
December				1	257	1,181	3	319	1,093	17	314	1,058						
January				5	266	1,226	2	330	1,102	5	320	1,058				1	317	858
Average	137	302	1,098	18	271	1,202	54	312	1,095	53	309	1,067	7	307	1,084	5	310	1,042
Ascension:																		
September				1	312	1,013	4	304	1,055	1	267	1,035						
October							2	295	1,055	4	318	1,013				3	304	1,010
November				1	334	1,140							2	287	1,036	2	313	1,035
December							4	310	1,016	1	324	1,067				1	316	921
January				4	330	1,058										2	318	1,074
Average	28	307	1,041	2	323	1,077	10	310	1,046	6	303	1,038	2	287	1,036	8	313	1,010
Avoyelles:																		
September				16	319	1,112	31	314	1,058	37	333	979	16	328	982	11	327	991
October				23	313	1,093	44	310	1,073	14	307	1,017	8	327	972	4	307	1,042
November				16	315	1,055	37	321	1,096	54	312	985	8	309	988	3	330	1,029
December				16	301	1,150	15	311	1,026	21	330	975	3	322	903			
January				12	293	1,130	5	333	1,092	5	326	1,013	2	317	985			
Average	401	318	1,022	83	308	1,108	132	318	1,069	131	322	994	37	321	966	18	321	1,021

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

LOUISIANA—Continued.

BY PARISHES AND MONTHS—Continued.

Parish and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Beauregard:																		
September				3	275	1,099												
October				1	305	1,099												
January																2	327	998
Average	6	309	1,049	4	290	1,099										2	327	998
Bienville:																		
September				1	315	991	1	313	1,067	1	322	1,007	3	313	959	2	299	903
October				3	307	1,127	1	313	896									
November													1	281	1,099			
Average	13	308	996	4	311	1,059	2	313	982	1	322	1,007	4	297	1,029	2	299	903
Bossier:																		
September										3	320	1,051	12	313	944			
October				4	292	1,093	11	292	1,039	1	320	1,042	16	314	934			
November							7	304	1,058	4	293	1,016	4	309	940			
December							8	313	1,016	8	309	1,017	2	306	1,001			
January							2	329	1,146	1	312	1,048	1	286	985			
Average	84	305	1,114	4	292	1,093	28	310	1,065	17	311	1,035	35	306	961			
Caddo:																		
September				13	301	1,112	4	314	1,017	4	306	1,039	18	314	975	17	323	1,010
October				17	299	1,111	12	297	1,035	7	302	1,073	9	314	994	2	321	1,017
November				4	285	1,054	5	297	1,080	10	303	1,020	3	314	1,035	3	307	1,055
December				3	292	1,134	13	313	1,080	30	307	1,048						
January				6	284	1,099	5	326	1,074	13	307	1,020						
Average	198	307	1,045	43	292	1,102	39	309	1,057	64	305	1,040	30	314	1,001	22	317	1,027

Calcasieu:																		
October																1	315	1,036
November				3	312	1,061				2	306	994						
December							1	296	1,048	1	348	991						
Average	8	313	1,035	3	312	1,061	1	296	1,048	3	327	993				1	315	1,036
Caldwell:																		
October				1	319	1,099	2	291	1,108				1	297	966			
November													1	354	963			
December				3	291	1,153												
January				5	273	1,137				1	323	978						
Average	14	309	1,045	9	294	1,130	2	291	1,108	1	323	978	2	326	965			
Cameron:																		
September													1	323	966			
October																1	262	1,074
Average	2	293	1,020										1	323	966	1	262	1,074
Catahoula:																		
September				1	317	1,035												
November				1	299	1,127												
January													1	296	966			
Average	3	303	1,024	2	308	1,081							1	296	966			
Claiborne:																		
September				1	274	1,048	7	314	1,004	3	308	1,010	6	312	1,001	1	320	975
October				2	293	1,089	7	317	994				2	310	918			
November							1	312	864	2	284	1,023	3	295	947			
December							1	326	966									
Average	36	305	998	3	284	1,069	16	317	957	5	296	1,034	11	306	955	1	320	975
Concordia:																		
September				1	348	925				2		1,067						
October				2	324	1,074												
January							1	344	1,073							1	304	1,067
Average	7	325	1,052	3	326	1,000	1,	344	1,073	2		1,067				1	304	1.067
De Soto:																		
September							3	291	988	4	296	1,029	13	290	1,032			
October				3	285	1,089	4	284	994	3	280	1,023	1	295	883	1	307	1,054
November							1	330	1,067	6	301	1,029						
December				1	279	1,146	5	304	1,023	3	288	1,039						
January							1	257	1,073	4	302	1,023						
Average	5	294	1,038	4	282	1,118	14	293	1,029	20	293	1,029	14	293	958	1	307	1,054

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

LOUISIANA—Continued.

BY PARISHES AND MONTHS—Continued.

Parish and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
East Baton Rouge:																		
September							4	300	1,102							3	296	1,086
October																5	265	1,073
November													1	277	1,108	1	290	1,077
December							3	305	1,077							2	301	953
January							4	317	1,092	1	303	922				1	300	1,080
Average	25	294	1,044				11	307	1,090	1	303	922	1	277	1,108	12	290	1,054
East Carroll:																		
September				1	346	941												
October				1	330	979												
December							1	352	1,045									
Average	3	345	1,003	2	338	960	1	352	1,045									
East Feliciana:																		
September				10	310	1,096	2	312	1,048				1	280	991			
October				2	303	1,102	3	299	1,029				1	283	998			
November				3	313	1,089												
Average	22	299	1,043	15	309	1,096	5	306	1,039				2	282	995			
Evangeline:																		
September				5	297	1,178	1	279	1,112	4	333	997	4	314	1,092			
October				1	323	1,058	1	336	1,042				3	308	1,058			
November				1	305	1,131	2	295	1,086	8	306	1,039						
December							1	285	1,067	6	319	1,067	1	304	1,064			
January				2	293	1,130	2	323	1,026									
Average	42	309	1,074	9	305	1,124	7	304	1,067	18	319	1,034	8	309	1,071			

Franklin:																		
September				5	297	1,137	3	267	1,130				4	323	1,051			
October				4	302	1,159												
November										2	294	969	1	305	956	1	314	1,083
December										5	327	1,055						
January										1	314	1,035						
Average	26	301	1,077	9	300	1,148	3	267	1,130	8	312	1,020	5	314	1,004	1	314	1,083
Grant:																		
September				1	321	1,058							2	338	931			
October				1	306	944	1	315	1,149				2	323	1,013			
November				6	294	1,124	4	327	1,115	1	320	1,016						
December				8	295	1,112	5	316	1,058									
January				1	273	1,187	4	321	1,058	2	316	1,020						
Average	38	317	1,043	17	298	1,085	14	320	1,095	3	318	1,018	4	331	972			
Iberia:																		
September													1	299	1,083			
Average	1	299	1,083										1	299	1,083			
Iberville:																		
September							1	293	1,054									
October				1	334	1,039	2	300	1,042									
November				1	325	1,089	2	293	1,096	3	330	918						
December							1	290	1,045									
January							1	327	1,099	1	331	868						
Average	13	321	1,008	2	330	1,064	7	301	1,067	4	331	893						
Jackson:																		
September										1	287	1,073						
October				1	289	1,064												
November													1	291	1,108			
Average	3	289	1,082	1	289	1,064				1	287	1,073	1	291	1,108			
Jefferson:																		
October				2	291	1,099							1	321	960			
January													1	319	963			
Average	4	306	1,031	2	291	1,099							2	320	962			
Jefferson Davis:																		
September							1	253										
November							2	297	1,115									
Average	3	275	1,115				3	275	1,115									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

LOUISIANA—Continued.

BY PARISHES AND MONTHS—Continued.

Parish and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
La Salle:																		
October													1	308	1,051			
November				1	295	1,102							1	307	1,080			
Average	3	302	1,084	1	295	1,102							2	308	1,066			
Lafayette:																		
September				6	302	1,200	3	321	1,112	2	319	1,124				2	315	1,035
October				2	299	1,172	1	275					1	301	1,099	1	338	934
November				1	302	1,188	3	307	1,051									
December				1	287					5	314	1,080						
January										1	309	998						
Average	29	308	1,084	10	298	1,187	7	301	1,082	8	314	1,067	1	301	1,099	3	327	985
Lafourche:																		
September										1	326	1,055						
November										1	320	956						
Average	2	323	1,006							2	323	1,006						
Lincoln:																		
September										1	276	865						
October										1	307	991						
November				1	305	1,035	1	315	1,086									
Average	4	304	1,016	1	305	1,035	1	315	1,086	2	292	928						
Livingston:																		
September				1	333	1,058	1	301	1,134	1	295	959						
October				7	311	1,067	5	288	1,121	1	314	985				3	292	1,083
November				1	293	1,124	4	324	1,127	2	293	985	1	293	982	1	293	1,051
December				1	295	1,169	1	324	1,134				1	307	991	1	291	950
January				4	296	1,150				1	326	979						
Average	37	303	1,047	14	306	1,114	11	309	1,129	5	307	977	2	300	987	5	292	1,028

Madison:																		
September				1	311	1,089	1	295	1,073				1	313	912			
November													1	293	1,134			
December				2	321	1,032												
January							1	372	997									
Average	7	318	1,040	3	316	1,061	2	334	1,035				2	303	1,023			
Morehouse:																		
September				7	299	1,029	3	265	1,017				3	307	997			
October							1	301	1,036				2	298	991			
November							1	303	1,089									
December				2	274	1,111	2	313	1,051									
January							1	330	1,105									
Average	22	297	1,041	9	287	1,070	8	302	1,060				5	303	994			
Natchitoches:																		
September				2	309	1,108	9	313	1,051	17	326	1,051	21	322	985			
October				11	310	1,067	14	302	1,035	13	307	994	8	304	959			
November				2	264	1,089	12	316	1,077	25	305	985	6	311	988	3	300	899
December				9	295	1,112	14	314	1,074	7	306	1,026	1	333	953	1	306	944
January				5	290	1,118	11	337	1,029	6	321	1,001						
Average	197	309	1,011	29	294	1,099	60	316	1,053	68	313	1,011	36	318	971	4	303	922
Ouachita:																		
September				5	298	1,039	2	301	1,064	2	337	982	6	326	1,048	6	324	988
October				2	297	1,064												
November							7	331	1,055	2	332	959						
January				1	277													
Average	33	318	1,025	8	291	1,057	9	316	1,060	4	335	971	6	326	1,048	6	324	988
Pointe Coupee:																		
September				1	308	1,051	4	319	1,039	3	329	988	1	319	1,013			
October				2	326	1,073	3	314	1,016				1	323	953			
November				2	320	1,092				3	316	969	4	309	963			
December							1	316	1,020	1	333	1,035				3	323	972
January							2	333	1,042							1	309	1,105
Average	32	326	1,023	5	318	1,072	10	321	1,029	7	326	997	6	350	976	4	316	1,039
Plaquemines:																		
September				1	320	1,067												
Average	1	320	1,067	1	320	1,067												
Rapides:																		
September				24	326	1,111	6	316	1,055	8	330	1,010	7	329	997	4	337	1,007
October				38	314	1,096	5	328	1,013				2	337	985	2	326	966
November				12	304	1,134	7	315	1,153	7	311	988				1	300	1,042
December				19	303	1,156	3	332	1,108	4	311	1,036						
January				13	293	1,175				4	314	1,032	1	317	1,089			
Average	167	319	1,059	106	308	1,134	21	323	1,082	23	317	1,017	10	328	1,024	7	321	1,038

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

LOUISIANA—Continued.

BY PARISHES AND MONTHS—Continued.

Parish and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Red River:																		
September				3	299	1,127				11	330	1,029	8	317	985			
October							3	291	1,086	3	274	1,007	5	314	982			
November										11	296	1,010	1	302	1,121			
December							8	306	1,048	4	315	1,055						
January				1	292	1,172	8	323	1,039	6	310	988						
Average	72	305	1,069	4	296	1,150	19	307	1,058	35	305	1,038	14	311	1,029			
Richland:																		
September				1	304	1,054	3	324	1,035	1	344	947	3	319	1,023			
October				7	306	1,140	2	314	1,045	2	337	1,007	1	307	1,020	1	314	991
November				1	302	1,130				4	312	972				3	334	1,032
December				1	301	1,055				11	324	1,023						
January										8	340	982						
Average	49	318	1,031	10	303	1,095	5	319	1,040	26	331	986	4	313	1,022	4	324	1,012
Sabine:																		
September				2	328	1,093				1	325	997	2	291	985			
October				7	306	1,099							1	302	1,035			
November				1	311	1,165	3	287	1,092									
January				1	307	1,124												
Average	18	306	1,055	11	313	1,120	3	287	1,092	1	325	997	3	297	1,010			
St. Bernard:																		
December							1	359	871									
Average	1	359	871				1	359	871									

St. Charles:																		
October										1	300	979						
December										1	304	960						
January							1	342	1,108									
Average	3	322	1,039				1	342	1,108	2	302	970						
St. Landry:																		
September				11	315	1,127	5	321	1,051	7	329	979				7	308	998
October				5	302	1,153	6	332	1,080	4	306	1,001	1	325	979	5	308	1,029
November				5	308	1,118	5	315	1,089	5	319	1,010	1	302	1,093	2	319	978
December				1	289	1,172	3	311	1,054	3	270	963				3	325	966
January				3	293	1,175	8	340	1,083	2	330	988						
Average	92	313	1,047	25	301	1,149	27	324	1,071	21	311	988	2	311	1,036	17	315	993
St. Martin:																		
September				2	333	1,203	4	303	1,181									
Average	6	318	1,192	2	333	1,203	4	303	1,181									
St. Tammany:																		
October				2	316	1,039	1	285	1,099									
November				4	306	1,061	1	320	1,121									
Average	8	307	1,080	6	311	1,050	2	302	1,110									
St. Mary:																		
October							1	285	1,035									
Average	1	285	1,035				1	285	1,035									
Tangipahoa:																		
September				2	308	1,086												
October										1	251	956						
Average	3	280	1,021	2	308	1,086				1	251	956						
Tensas:																		
September				1	307	1,023	5	333	1,013									
October				1	357	978												
November							4	327	1,029									
December							11	332	1,051									
January							6	347	1,017	1	327	991						
Average	29	331	1,007	2	332	1,001	26	335	1,028	1	327	991						
Union:																		
September							1	311	956				3	325	934			
October													5	315	922			
November				1	297	1,074	1	333	1,086				6	314	972			
December													1	301	1,004			
Average	18	331	1,018	1	297	1,074	2	322	1,021				15	314	958			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

LOUISIANA—Continued.

BY PARISHES AND MONTHS—Continued.

Parish and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Vermilion:																		
October																2	294	1,026
November																1	314	969
December										1	339	1,080				1	271	1,020
January																2	309	963
Average	7	318	1,038							1	339	1,080				6	297	995
Vernon:																		
October													1	336	953			
November										1	312	985						
Average	2	324	969							1	312	985	1	336	953			
Washington:																		
September				2	317	1,130	1	305	1,020									
October							1	285	953									
November				2	309	1,124	5	324	1,054									
Average	11	309	1,068	4	313	1,127	7	305	1,009									
Webster:																		
September													1	322	963			
October				1	311	1,118							1	323	950			
November													2	311	918			
Average	5	315	1,031	1	311	1,118							4	319	944			
West Baton Rouge:																		
September													3	341	956			
Average	3	341	956										3	341	956			

West Carroll:																		
September				4	302	1,146	2	331	1,001	2	328	1,016	3	324	1,045	3	311	972
October				7	289	1,086	10	323	1,045				3	318	1,026			
November							4	323	1,080									
December				3	283	1,099	1	293	1,143									
Average	42	314	1,040	14	291	1,110	17	318	1,067	2	328	1,016	6	321	1,036	3	311	972
West Feliciana:																		
September				1	271	1,086	2	297	1,054	1	333	969	1	278	1,039			
October				3	307	1,054	5	312	1,074							2	291	1,099
November							1	315	1,017							2	322	1,010
December							1	327	1,102							1	306	1,016
January																2	289	1,032
Average	22	303	1,036	4	289	1,070	9	313	1,062	1	333	969	1	278	1,038	7	302	1,039
Winn:																		
September													1	302	1,035			
October													1	289	975			
November							1	297	1,216									
December							1	292	1,093	1	324	991						
Average	5	305	1,050				2	295	1,155	1	324	991	2	296	1,005			

MISSISSIPPI.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	2,351	311	1,013	1,439	302	1,045	370	317	982	185	321	958	188	312	990	169	316	995
Adams	6	318	960	3	306	1,014	1	323	842	2	326	1,024						
Alcorn	11	309	986	6	295	1,053	3	313	985	1	298	950	1	328	956			
Amite	19	314	1,088	16	302	1,096	2	332	1,079	1	308	1,089						
Attala	11	306	1,018	6	311	1,074							1	300	985	4	307	995
Benton	6	310	1,000	2	300	1,025	2	314	960							2	315	1,014

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Bolivar	306	321	982	207	315	1,017	38	334	959	24	319	956	26	317	1,021	11	321	958
Calhoun	7	304	1,008	2	297	1,036	5	311	980									
Carroll	4	318	1,088	4	318	1,088												
Chickasaw	20	314	961	4	302	985	12	318	980	1	344	918	3	291				
Choctaw	2	294	1,061	2	294	1,061												
Claiborne	8	318	1,007	5	285	1,076				1	330	966	1	333	1,045	1	323	940
Clarke	2	306	1,026	1	318	1,073										1	293	979
Clay	42	307	988				4	308	1,015	2	317	931	18	301	986	18	302	1,019
Coahoma	174	319	988	92	315	1,044	25	331	961	17	330	967	21	314	999	19	305	971
Copiah	10	303	1,059	9	298	1,063	1	307	1,055									
Covington	4	329	1,071	3	306	1,071	1	351										
De Soto	169	310	967	113	289	991	37	311	903	9	325	959	2	306	975	8	320	1,005
Forrest	8	310	971	8	310	971												
Franklin	2	288	1,098	2	288	1,098												
George	1	313	988										1	313	988			
Greene	10	318	1,039	10	318	1,039												
Grenada	34	311	961	1	339	906	5	317	997				15	296	975	13	392	966
Hancock	1	281	921							1	281	921						
Harrison	6	291	1,041	6	291	1,041												
Hinds	105	315	1,015	45	306	1,061	10	317	1,041	9	321	983	13	312	994	28	319	997
Holmes	31	322	1,014	27	313	1,058	4	330	970									
Issaquena	2	314	943	3	327	984							1	300	902			
Itawamba	2	314	883				2	314	883									
Jackson	2	326	1,026	1	308	1,074							1	344	978			
Jefferson	7	311	1,114	6	299	1,101	1	322	1,127									

Jefferson Davis	2	303	1,045	2	303	1,045												
Jones	4	320	1,055	1	340	1,137	2	312	1,029				1	307	998			
Kemper	2	314	999	2	314	999												
Lafayette	7	313	958	3	290	1,030	1	361	975	1	295	883	2	304	944			
Lamar	5	314	1,031	3	309	1,112	2	318	949									
Lauderdale	44	317	981				3	318	982	3	328	958	21	302	985	17	318	998
Lawrence	20	321	1,010	19	304	1,085	1	338	934									
Leake	1	254	1,077	1	254	1,077												
Lee	35	315	993	20	289	1,031	4	307	965	1	344	1,017	3	320	944	7	315	1,007
Leflore	78	346	979	71	327	1,028	2	372	960	3	348	909	2	336	1,020			
Lincoln	4	323	1,002							1	333	985	1	313	1,055	2	324	965
Lowndes	46	326	992	36	296	1,051	6	355	1,024	2	333	865				2	319	1,026
Madison	16	321	980	13	294	1,062	2	333	990	1	337	887						
Marion	10	298	1,100	10	298	1,100												
Marshall	23	304	974	12	279	1,007	4	317	957	3	309		1	310	959	3	305	972
Monroe	21	308	991	1	274	1,016				4	328	958	7	318	999	9	313	991
Montgomery	6	309	1,095	3	306	1,112	1	324	1,197				2	296	977			
Neshoba	1	296	1,067	1	296	1,067												
Newton	12	315	1,006	9	300	1,043	3	329	969									
Noxubee	1	276		1	276													
Panola	138	301	982	68	279	1,018	36	302	951	19	314	947	13	303	991	2	308	1,004
Perry	5	324	1,034	2	297	1,074				1	352	1,016	1	319	1,036	1	327	1,010
Pike	17	299	1,042	11	294	1,099	3	317	1,059	2	303	993	1	281	1,016			
Pontotoc	5	317	1,029				1	329								4	304	1,029
Prentiss	10	302	939	3	290	1,013	5	316	921	2	299	883						
Quitman	72	317	1,051	38	307	1,052	18	330	967	7	314	1,074	8	306	1,062	1	326	1,102
Rankin	1	308	994				1	308	994									
Scott	11	301	1,077	11	301	1,077												
Sharkey	12	327	968	2	342	972	6	339	966	1	306	991	3	321	943			
Simpson	14	309	1,063	14	309	1,063												
Smith	10	308	1,060	10	308	1,060												
Sunflower	259	323	997	223	315	1,046	27	329	973	8	309	1,028				1	338	941
Tallahatchie	130	316	1,012	94	304	1,043	17	313	973	10	310	944	2	327	1,043	7	327	1,058
Tate	48	293	972	37	288	1,020	5	302	931	4	299	959	2	281	979			
Tippah	6	299	1,006	2	272	1,044	4	326	967									
Tishomingo	4	322	921				2	298	920				1	337	868	1	330	975
Tunica	81	325	979	45	310	996	16	336	925	12	339	961	7	321	1,001	1	318	1,010
Union	15	309	974	2	287	998	4	314	960	5	325	929	1	310		3	310	1,010
Walthall	13	312	1,020				6	310	1,033	7	313	1,007						
Warren	13	321	978	6	306	970	6	327	1,035	1	330	928						
Washington	113	328	956	61	320	1,000	27	330	966	18	333	945	4	327	950	3	331	917
Webster	5	308	1,060	5	308	1,060												
Wilkinson	4	311	1,122	4	311	1,122												
Winston	2	305	1,094	1	300	1,067							1	309	1,121			
Yalobusha	4	290	1,065	4	290	1,065												
Yazoo	8	328	955	5	305	1,038	2	343	981	1	336	845						

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Adams:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				2	327	1,036												
October										1	331	1,051						
November							1	323	842	1	321	997						
January				1	284	991												
Average	6	318	960	3	306	1,014	1	323	842	2	326	1,024						
Alcorn:																		
September				2	295	1,051	2	331	966	1	298	950						
October				2	287	1,092							1	328	956			
November							1	295	1,004									
December				2	302	1,016												
Average	11	309	986	6	295	1,053	3	313	985	1	298	950	1	328	956			
Amite:																		
September				8	298	1,108												
October				3	305	1,140	1	321	1,115	1	308	1,089						
November				3	293	1,086												
December				2	312	1,048												
January							1	342	1,042									
Average	19	314	1,088	16	302	1,096	2	332	1,079	1	308	1,089						
Attala:																		
September				5	288	1,070							1	300	985	3	323	928
October																1	291	1,061
November				1	333	1,077												
Average	11	306	1,018	6	311	1,074							1	300	985	4	307	995

Benton:																		
October																1	318	1,010
November				1	331	972	2	314	960							1	311	1,017
December				1	268	1,077												
Average	6	310	1,000	2	300	1,025	2	314	960							2	315	1,014
Bolivar:																		
September				74	314	998	17	327	931	17	319	956	12	334	960	10	327	934
October				37	316	1,010	15	328	1,010	2	307		2	330		1	315	982
November				49	315	1,051	2	348	972	2	327		9	312	1,016			
December				20	314	1,004	3	324	1,007	2	317		2	298	1,013			
January				27	314	1,023	1	345	877	1	327		1	311	1,093			
Average	306	321	982	207	315	1,017	38	334	959	24	319	956	26	317	1,021	11	321	958
Calhoun:																		
September				2	297	1,036												
October							3	308	1,016									
November							2	314	944									
Average	7	304	1,008	2	297	1,036	5	311	980									
Carroll:																		
October				3	316	1,067												
November				1	319	1,108												
Average	4	318	1,088	4	318	1,088												
Chickasaw:																		
September				3	290	1,016				1	344	918						
October				1	313	953	4	317	985				3	291				
November							7	325	975									
December							1	312	979									
Average	20	314	961	4	302	985	12	318	980	1	344	918	3	291				
Choctaw:																		
December				2	294	1,061												
Average	2	294	1,061	2	294	1,061												
Claiborne:																		
September				1	286	1,070				1	330	966						
October				1	273	1,051												
November				3	296	1,108							1	333	1,045			
January																1	323	940
Average	8	318	1,007	5	285	1,076				1	330	966	1	333	1,045	1	323	940
Clarke:																		
September				1	318	1,073												
November																1	293	979
Average	2	306	1,026	1	318	1,073										1	293	979

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Clay:																		
September										2	317	931	2	306	991	2	303	1,055
October							1	290	1,013				5	310	982	3	296	1,020
November							3	325	1,017				5	300	988	6	302	1,035
December													4	301	1,004	4	300	1,010
January													2	287	963	3	308	975
Average	42	307	988				4	308	1,015	2	317	931	18	301	986	18	302	1,019
Coahoma:																		
September				25	318	1,048	4	326	978	11	324	937	6	307	982	5	319	963
October				21	311	1,032	4	330	944	1	350		2	323	975	2	320	956
November				17	320	1,055	13	333	991	1	352	909	3	326	1,017	5	300	966
December				13	315	1,051	3	341	988	1	319	1,054	6	303	1,007	4	289	978
January				16	309	1,032	1	325	902	3	304	966	4	313	1,013	3	295	994
Average	174	319	988	92	315	1,044	25	331	961	17	330	967	21	314	999	19	305	971
Copiah:																		
September				2	304	1,070	1	307	1,055									
October				5	299	1,083												
November				1	288	1,080												
December				1	299	1,020												
Average	10	303	1,059	9	298	1,063	1	307	1,055									
Covington:																		
September				1	300	1,017												
November				2	311	1,124												
December							1	351										
Average	4	329	1,071	3	306	1,071	1	351										

De Soto:																		
September				36	280	998	4	319	941	9	325	959				5	316	978
October				39	287	1,007	12	321	912							2	334	1,026
November				16	295	972	10	319	909									
December				15	284	1,001	4	311	864				2	306	975			
January				7	297	978	7	287	887							1	311	1,010
Average	169	310	967	113	289	991	37	311	903	9	325	959	2	306	975	8	320	1,005
Forrest:																		
September				4	304	998												
October				1	331	890												
November				1	298	997												
January				2	307	997												
Average	8	310	971	8	310	971												
Franklin:																		
October				1	298	1,093												
November				1	278	1,102												
Average	2	288	1,098	2	288	1,098												
George:																		
October													1	313	988			
Average	1	313	988										1	313	988			
Greene:																		
September				1	319	1,039												
October				3	312	1,055												
November				3	317	1,020												
December				3	322	1,042												
Average	10	318	1,039	10	318	1,039												
Grenada:																		
September				1	339	906										2	298	991
October													4	310	960	4	297	931
November							5	317	997				5	298	991	1	292	972
December													3	288	985	4	287	975
January													3	287	963	2	284	963
Average	34	311	961	1	339	906	5	317	997				15	296	975	13	292	966
Hancock:																		
September										1	281	921						
Average	1	281	921							1	281	921						

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Harrison:																		
September				2	292	1,036												
October				1	287	1,032												
November				3	295	1,055												
Average	6	291	1,041	6	291	1,041												
Hinds:																		
September				19	304	1,055	2	327	1,067	7	321	963	4	312	950	6	328	979
October				13	298	1,073	3	307	1,020	1	329	1,020	5	318	1,004	4	317	994
November				10	306	1,096	5	316	1,036				3	305	1,004	6	316	1,010
December				2	312	1,042										9	316	1,016
January				1	311	1,039				1	314	966	1	313	1,017	3	319	985
Average	105	315	1,015	45	306	1,061	10	317	1,041	9	321	983	13	312	994	28	319	997
Holmes:																		
September				12	306	1,035	1	328	903									
October				5	308	1,061	1	328	1,074									
November				8	321	1,032	2	335	934									
December				2	318	1,105												
Average	31	322	1,014	27	313	1,058	4	330	970									
Issaquena:																		
September				1	327	988												
October				1	340	988												
November													1	300	902			
December				1	313	975												
Average	2	314	943	3	327	984							1	300	902			

Itawamba:																		
November							1	332	921									
January							1	296	845									
Average	2	314	883				2	314	883									
Jackson:																		
September													1	344	978			
December				1	308	1,074												
Average	2	326	1,026	1	308	1,074							1	344	978			
Jefferson:																		
September				1	301	1,067												
October				2	302	1,111	1	322	1,127									
November				1	295	1,124												
Average	7	311	1,114	6	299	1,101	1	322	1,127									
Jefferson Davis:																		
October				1	299	1,032												
November				1	306	1,058												
Average	2	303	1,045	2	303	1,045												
Jones:																		
September							1	304	1,051									
October													1	307	998			
November							1	320	1,007									
December				1	340	1,137												
Average	4	320	1,055	1	340	1,137	2	312	1,029				1	307	998			
Kemper:																		
September				1	321	994												
January				1	307	1,004												
Average	2	314	999	2	314	999												
Lafayette:																		
September				2	265	1,020				1	295	883						
November							1	361	974				2	304	944			
January				1	315	1,039												
Average	7	313	958	3	290	1,030	1	361	974	1	295	883	2	304	944			
Lamar:																		
September				2	308	1,143												
November				1	310	1,080	1	321	988									
January							1	314	909									
Average	5	314	1,031	3	309	1,112	2	318	949									

TABLE VI.—*Yields of oil and meal, by counties, as compiled by analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Lauderdale:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September										1	328	950	4	303	959	2	330	979
October										2	327	966	5	312	985	4	314	978
November							3	318	982				4	299	979	5	320	1,001
December													6	295	991	3	314	1,029
January													2	303	1,010	3	313	1,004
Average	44	317	981				3	318	982	3	328	958	21	302	985	17	318	998
Lawrence:																		
September				9	304	1,083												
October				7	303	1,093	1	338	934									
November				2	314	1,096												
December				1	293	1,067												
Average	20	321	1,010	19	304	1,085	1	338	934									
Leake:																		
September				1	254	1,077												
Average	1	254	1,077	1	254	1,077												
Lee:																		
September				9	282	1,026	1	298	925				2	333	944			
October				11	295	1,035	1	316	1,029	1	344	1,017				3	308	979
November							2	307	940				1	307		3	329	1,001
December																1	309	1,042
Average	35	315	993	20	289	1,031	4	307	965	1	344	1,017	3	320	944	7	315	1,007

LeFlore:																		
September				14	325	1,016				3	348	909						
October				43	323	1,020	2	372	960									
November				11	328	1,023												
December				3	332	1,054												
January													2	336	1,020			
Average	78	346	979	71	327	1,028	2	372	960	3	348	909	2	336	1,020			
Lincoln:																		
September										1	333	985						
October													1	313	1,055			
November																1	327	988
December																1	320	941
Average	4	323	1,002							1	333	985	1	313	1,055	2	324	965
Lowndes:																		
September				5	316	1,067	4	377	1,045	2	333	865				2	319	1,026
October				2	283	1,055	1	347	1,048									
November				4	295	1,073	1	341	979									
December				18	292	1,023												
January				7	296	1,039												
Average	46	326	992	36	296	1,051	6	355	1,024	2	333	865				2	319	1,026
Madison:																		
September				5	301	1,067				1	337	887						
October				3	300	1,077												
November				3	281	1,067	1	348	903									
December				2	294	1,035	1	317	1,077									
Average	16	321	980	13	294	1,062	2	333	990	1	337	887						
Marion:																		
September				4	297	1,083												
October				3	285	1,083												
November				3	311	1,134												
Average	10	298	1,100	10	298	1,100												
Marshall:																		
September				3	254	969				1	318							
October				1	277	1,045	1	329	959	1	309		1	310	959	2	322	972
November				3	288	1,016	2	304	972							1	287	
December				3	293	1,013	1	319	940	1	301							
January				2	284	994												
Average	23	304	974	12	279	1,007	4	317	957	3	309		1	310	959	3	305	972

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Monroe:																		
September				1	274	1,016				1	320	1,010	4	305	963	2	312	1,004
October										1	338	912	2	322	994			
November										2	327	953				3	309	997
December													1	327	1,039	2	314	994
January																2	316	969
Average	21	308	991	1	274	1,016				4	328	958	7	318	999	9	313	991
Montgomery:																		
October				2	293	1,099							1	272	953			
November													1	319	1,001			
December							1	324	1,197									
January				1	318	1,124												
Average	6	309	1,095	3	306	1,112	1	324	1,197				2	296	977			
Neshoba:																		
Sept				1	296	1,067												
Average	1	296	1,067	1	296	1,067												
Newton:																		
September				4	300	1,029	1	314	899									
November				4	305	1,064	1	342	944									
December				1	295	1,035	1	332	1,064									
Average	12	315	1,006	9	300	1,043	3	329	969									
Noxubee:																		
October				1	276													
Average	1	276		1	276													

Panola:																		
September				30	287	1,007	4	299	947	14	305	925	5	294	928	2	308	1,004
October				22	278	972	10	313	963	2	338	991	3	302	928			
November				7	281	1,064	19	314	915	1	338		3	307	1,007			
December				5	277	1,058	2	295	1,042	1	301	963	2	310	1,099			
January				4	273	991	1	287	887	1	287	909						
Average	138	301	982	68	279	1,018	36	302	951	19	314	947	13	303	991	2	308	1,004
Perry:																		
September				1	293	1,048										1	327	1,010
November				1	301	1,099							1	319	1,036			
December										1	352	1,016						
Average	5	324	1,034	2	297	1,074				1	352	1,016	1	319	1,036	1	327	1,010
Pike:																		
September				4	302	1,102				1	303	1,020						
October				3	294	1,102	1	306	1,077									
November				4	287	1,093	1	333	1,017	1	303	966						
December													1	281	1,016			
January							1	312	1,083									
Average	17	299	1,042	11	294	1,099	3	317	1,059	2	303	993	1	281	1,016			
Pontotoc:																		
September																1	331	1,023
October							1	329								1	294	1,051
November																2	287	1,013
Average	5	317	1,029				1	329								4	304	1,029
Prentiss:																		
September				1	274	1,016				1	296	883						
October				2	305	1,010												
November							5	316	921	1	301							
Average	10	302	939	3	290	1,013	5	316	921	2	299	883						
Quitman:																		
September				19	309	1,026	3	350	947	4	300	1,074	3	300	1,010			
October				6	303	1,039	8	325	972	1	316					1	326	1,102
November				6	322	1,058	6	329	982	1	319		4	320	1,070			
December				5	290	1,080	1	315		1	320		1	298	1,007			
January				2	313	1,058												
Average	72	317	1,051	38	307	1,052	18	330	967	7	314	1,074	8	306	1,062	1	326	1,102
Rankin:																		
October							1	308	994									
Average	1	308	994				1	308	994									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Scott:																		
September				3	295	1,077												
October				2	307	1,058												
November				4	302	1,096												
Average	11	301	1,077	11	301	1,077												
Sharkey:																		
September							6	339	966	1	306	991						
October													2	327	925			
November				2	342	972							1	314	960			
Average	12	327	968	2	342	972	6	339	966	1	306	991	3	321	943			
Simpson:																		
September				5	305	1,093												
October				4	312	1,016												
November				5	311	1,080												
Average	14	309	1,063	14	309	1,063												
Smith:																		
September				4	312	991												
October				5	304	1,058												
November				1	307	1,130												
Average	10	308	1,060	10	308	1,060												
Sunflower:																		
September				55	314	1,036	14	325	960	7	304	1,017				1	338	941
October				55	309	1,042	5	333	969	1	314	1,039						
November				46	315	1,064	7	323	985									
December				24	311	1,045	1	336	978									
January				43	326	1,042												
Average	259	323	997	223	315	1,046	27	329	973	8	309	1,028				1	338	941

Tallahatchie:																		
September				14	310	1,001	6	301	985	9	297	960				3	331	1,042
October				20	307	1,039	2	330	1,017	1	323	928				4	322	1,074
November				32	306	1,045	8	313	991				1	326	1,073			
December				13	297	1,067	1	306	899				1	327	1,013			
January				15	300	1,064												
Average	130	316	1,012	94	304	1,043	17	313	973	10	310	944	2	327	1,043	7	327	1,058
Tate:																		
September				10	276	1,004				1	302							
October				13	290	1,020				2	298	959						
November				6	275	1,036	1	291	921	1	298		1	279				
December				6	303	1,007	2	304	947									
January				2	295	1,035	2	310	925				1	283	979			
Average	48	293	972	37	288	1,020	5	302	931	4	299	959	2	281	979			
Tippah:																		
September				1	273	1,020												
October				1	270	1,067	2	324	956									
November							1	325	963									
December							1	329	982									
Average	6	299	1,006	2	272	1,044	4	326	967									
Tishomingo:																		
September							1	281	845				1	337	868	1	330	975
November							1	315	994									
Average	4	322	921				2	298	920				1	337	868	1	330	975
Tunica:																		
September				2	299	1,089	3	327	1,042	11	339	950				1	318	1,010
October				14	319	966	3	337	979				1	347	1,010			
November				17	310	1,010	7	338	909	1	339	972	4	304	1,010			
December				3	306	956	2	346	861				1	306	1,007			
January				9	317	959	1	331	836				1	325	978			
Average	81	325	979	45	310	996	16	336	925	12	339	961	7	321	1,001	1	318	1,010
Union:																		
September				1	283	1,013	1	294	972	2	324	902				2	324	1,010
October										2	337	956	1	310		1	295	
November				1	291	982	2	321	947									
December							1	326		1	315							
Average	15	309	974	2	287	998	4	314	960	5	325	929	1	310		3	310	1,010
Walthall:																		
September							1	316	975									
October							3	299	1,051	1	302	1,070						
November							2	314	1,074	4	306	982						
December										1	327	979						
January										1	317	997						
Average	13	312	1,020				6	310	1,033	7	313	1,007						

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSISSIPPI—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Warren:																		
September				1	300	998	3	332	953									
October				1	300	925	1	329	1,061									
November				4	319	988				1	330	928						
December							2	319	1,092									
Average	13	321	978	6	306	970	6	327	1,035	1	330	928						
Washington:																		
September				26	320	979	24	330	950	14	337	880				2	327	918
October				2	305	991				1	334	1,029						
November				21	315	998							3	308	985	1	335	915
December				10	320	998	2	328	959				1	346	915			
January				2	338	1,032	1	331	988	3	327	925						
Average	113	328	956	61	320	1,000	27	330	966	18	333	945	4	327	950	3	331	917
Webster:																		
September				2	318	1,058												
November				2	292	1,007												
January				1	314	1,115												
Average	5	308	1,060	5	308	1,060												
Wilkinson:																		
September				1	321	1,216												
October				2	295	1,070												
November				1	318	1,080												
Average	4	311	1,122	4	311	1,122												
Winston:																		
October													1	309	1,121			
November				1	300	1,067												
Average	2	305	1,094	1	300	1,037							1	309	1,121			

Yalobusha:																		
September				2	284	1,032												
October				1	281	1,102												
November				1	302	1,061												
Average	4	290	1,065	4	290	1,065												
Yazoo:																		
September				1	333	1,007				1	336	845						
October				1	264	1,111	1	357	944									
November				3	318	997												
December							1	329	1,017									
Average	8	328	955	5	305	1,038	2	343	981	1	336	845						

MISSOURI.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	338	295	1,005	151	287	989	19	338	940	15	300	970	146	315	999	7	300	1,005
Butler	8	308	1,008	3	290	1,044							5	326	971			
Callaway	3	277	1,042	3	277	1,042												
Clay	6	309	983										6	309	983			
Dunklin	180	306	946	53	275	832	6	332	931	8	312	976	111	308	988	2	305	1,004
Jasper	1	265		1	265													
Jackson	1	252		1	252													
Mississippi	3	332	982	1	352	944							2	311	1,020			
Lafayette	1	256														1	256	
New Madrid	26	305	992	20	297	982				1	285		4	306	972	1	333	1,023
Pemiscot	84	313	982	59	288	1,031	13	344	949	6	302	963	4	304	980	2	325	989
Ripley	3	311	1,064	2	277								1	344	1,064			
Saline	1	281														1	281	
Stoddard	20	308	1,015	8	294	1,047							12	321	982			
Scott	1	310	1,032										1	310	1,032			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

MISSOURI—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Butler:																		
October				1	317	1,105							3	329	978			
November													2	323	963			
January				2	263	982												
Average	8	308	1,008	3	290	1,044							5	326	971			
Clay:																		
October													2	331	953			
November													3	308	1,010			
December													1	289	985			
Average	6	309	983										6	309	983			
Callaway:																		
October				1	267	1,042												
December				2	287													
Average	3	277	1,042	3	277	1,042												
Dunklin:																		
September				9	251	1,080				1	308	1,013	9	318	1,004			
October				14	258	1,058	2	299	1,004	4	323	997	40	316	982	2	305	1,004
November				5	288	1,093	3	364	931	1	302		42	317	998			
December				23	285		1	333	858	2	315	918	18	299	1,007			
January				2	295	928							2	290	947			
Average	180	306	946	53	275	832	6	332	931	8	312	976	111	308	988	2	305	1,004
Mississippi:																		
October				1	352	944												
November													1	309	1,054			
December													1	313	985			
Average	3	332	982	1	352	944							2	311	1,020			

Jasper:																		
September				1	265													
Average	1	265		1	265													
Jackson:																		
October				1	252													
Average	1	252		1	252													
Lafayette:																		
November																1	256	
Average	1	256														1	256	
New Madrid:																		
September				5	277	1,051												
October				8	292	991							1	343	922	1	333	1,023
November				3	302								1	278	991			
December				3	322								2	297	1,004			
January				1	292	903				1	285							
Average	26	305	992	20	297	982				1	285		4	306	972	1	333	1,023
Pemiscot:																		
September				16	269	1,086				1	287	1,083						
October				22	290	1,061	5	348	988	1	258	991	3	305	931	1	329	998
November				3	279		3	355	953	2	333	953				1	321	979
December				12	314	1,035	5	329	906	1	310	906	1	303	1,029			
January				6	288	940				1	323	883						
Average	84	313	982	59	288	1,031	13	344	949	6	302	963	4	304	980	2	325	989
Ripley:																		
September				1	260													
October				1	294													
November													1	344	1,064			
Average	3	311	1,064	2	277								1	344	1,064			
Saline:																		
November																1	281	
Average	1	281														1	281	
Stoddard:																		
October				2	268								7	331	975			
November				2	311	1,016							4	322	959			
December				4	302	1,077							1	311	1,013			
Average	20	308	1,015	8	294	1,047							12	321	982			
Scott:																		
October													1	310	1,032			
Average	1	310	1,032										1	310	1,032			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NEW MEXICO.

BY COUNTIES.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	2	353	1,045	1	362	.....	.....	.....	.....	1	344	1,045	.....	.....	.....	.....	.....	.....
Eddy	2	353	1,045	1	362	.....	.....	.....	.....	1	344	1,045	.....	.....	.....	.....	.....	.....

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Eddy:																		
October	.....	.....	.....	1	362	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	344	1,045	.....	.....	.....	.....	.....	.....
Average	2	353	1,045	1	362	.....	.....	.....	.....	1	344	1,045	.....	.....	.....	.....	.....	.....

NORTH CAROLINA.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	4,065	328	932	1,454	317	977	777	318	901	578	338	899	575	341	955	681	331	949
Alamance	7	332	942	5	323	957	1	323	865				1	350	1,004			
Alexander	6	324	963	1	292	1,023	1	355	883							4	335	982
Anson	250	333	934	86	303	1,002	20	318	881	20	356	899	73	340	990	51	349	897
Ashe	8	330	938	2	315	1,007	2	323	891	1	339	918				3	341	936
Beaufort	4	325	915				2	304	911				2	346	918			
Bertie	6	312	937	1	303	959	3	308	912							2	326	940
Bladen	69	321	958	23	313	999	11	297	912	6	334	948	15	337	971	14	325	960
Buncombe	3	320	933				2	307	858				1	333	1,007			
Burke	3	340	950										1	332	953	2	347	947
Cabarrus	169	327	941	22	306	960	6	321	925	4	340	907	44	347	933	93	323	980
Camden	1	296	1,039	1	296	1,039												
Caldwell	1	342	918													1	342	918
Carteret	3	306	927				2	298	922							1	314	931
Catawba	14	340	922	2	340	912				2	335	885	2	352	915	8	331	974
Chatham	29	328	952	10	317	1,007	8	319	880	5	339	908	3	336	947	3	330	1,018
Cherokee	2	338	939				1	318	864				1	358	1,013			
Chowan	3	310	961							1	284	998	2	335	924			
Cleveland	129	331	900	33	313	945	9	318	841	38	337	863	12	351	903	37	335	946
Columbus	16	321	989	13	315	1,044	1	316	906				1	341	953	1	313	1,051
Craven	2	361	876							2	361	876						
Cumberland	144	317	948	78	303	965	44	306	914	7	334	923	1	318	953	14	322	987
Currituck	5	319	907				3	318	904	2	319	909						
Davidson	18	312	956	4	303	973	8	295	938	2	324	880				4	327	1,034
Davie	35	325	905	16	312	954	7	307	885	9	335	858	3	347	922			
Duplin	31	323	968	20	322	990	11	324	945									
Durham	2	315	893				1	300	883							1	330	903
Edgecombe	48	335	913	19	319	921	5	326	938	2	341	839	8	347	985	14	340	881
Franklin	3	348	936	1	358	985	2	338	886									
Gaston	87	329	936	41	309	967	9	319	913	10	339	878	16	340	963	11	336	957
Gates	3	329	958										2	335	1,042	1	323	874

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Graham	2	336	1,012	2	336	1,012												
Granville	2	334	920													2	334	920
Greene	7	337	923	1	339	950	2	303	852	2	352	933	2	354	957			
Halifax	25	337	921	9	330	896	9	333	903	2	348	861	4	331	991	1	343	956
Harnett	89	322	929	49	311	959	18	302	901	11	338	900	4	337	906	7	323	980
Haywood	2	321	866				1	298	842							1	343	890
Hertford	2	327	977	1	318	1,032	1	335	922									
Hoke	127	326	952	47	306	986	27	320	902	15	326	884	22	351	1,005	16	329	985
Iredell	23	339	943	1	325	978	1	332	855	18	339	907	1	369	969	2	328	1,007
Johnston	140	325	921	95	313	936	19	312	912	16	339	882	5	333	915	5	330	959
Jones	1	337	903										1	337	903			
Lee	29	330	928	11	325	987	9	323	868	4	341	902	2	336	931	3	324	954
Lenior	31	323	943	4	323	970	5	304	951	14	334	916	4	331	959	4	325	921
Lincoln	47	333	928	14	324	963	10	330	922	6	328	874	1	347	902	16	334	980
McDowell	4	328	994	1	301	1,042	2	329	921				1	327	1,020			
Macon	1	319	982													1	319	982
Madison	10	322	955	4	301	1,034	4	320	906	2	345	925						
Martin	6	325	896													6	325	896
Mecklenburg	403	330	922	259	311	939	53	332	896	45	340	878	21	335	934	25	332	964
Montgomery	17	326	944	2	306	1,009	4	334	861	2	324	944	5	338	969	4	329	935
Moore	12	317	1,007	3	310	1,095	5	338	986	1	314	959				3	305	986
Nash	18	328	930	5	336	936	7	299	907	1	360	903	1	316	1,026	4	331	878
New Hanover	1	342	846													1	342	846
Northampton	20	336	936	8	342	973	3	313	874	3	339	983	3	341	1,021	3	347	918
Onslow	3	350	886							2	342	887				1	358	884
Orange	22	322	938	10	311	963	8	318	888	1	318	903	1	332	1,004	2	330	932
Pamlico	1	311	706										1	311	706			
Pasquotank	6	338	871				5	314	865	1	361	877						
Pender	10	305	1,017	10	305	1,017												
Perquimans	3	330	936				1	309	944	1	349	937	1	333	928			

Person	1	334	972				1	334	972									
Pitt	23	333	961	8	320	985	6	302	907	1	372	944	1	346	1,035	7	327	933
Randolph	2	313	896				1	287	912	1	340	880						
Richmond	106	331	945	26	305	993	34	332	909	9	340	909	20	340	986	17	338	927
Robeson	425	327	952	78	300	999	98	318	925	81	335	917	87	348	952	81	33	969
Rockingham	4	329	936							1	332	855				3	326	1,016
Rowan	51	332	936	11	320	951	16	319	894	16	339	907	4	360	921	4	322	1,007
Rutherford	51	342	924	8	354	949	2	338	928	16	339	882	7	349	884	18	330	976
Sampson	49	327	938	29	318	971	9	314	948	7	334	881	1	350	918	3	321	972
Scotland	216	324	953	68	298	1,003	38	318	914	35	332	905	62	339	1,001	13	335	941
Stanley	51	326	922	10	309	974	9	309	879	12	335	861	10	348	958	10	330	938
Transylvania	1	306	956													1	306	956
Union	585	323	912	154	308	972	107	311	885	110	337	866	95	330	946	119	331	892
Vance	9	349	919	2	350	922	3	337	871	1	352	890	2	356	1,001	1	352	909
Wake	92	333	934	22	310	965	42	332	911	11	345	857	8	343	985	9	333	954
Warren	10	340	887	2	341	922	6	339	838	1	340	871	1	338	918			
Wautauga	3	332	922							2	334	919				1	330	925
Wayne	80	331	966	42	325	971	18	315	922	14	344	924	4	345	957	2	326	1,058
Wilkes	21	317	950	6	312	983	15	321	916									
Wilson	115	324	934	74	325	938	18	314	921	2	317	909	5	331	943	16	334	961
Yadkin	5	314	885				1	310	868							4	318	901

By Counties and Months.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Alamance:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September													1	350	1,004			
October				1	333	925												
November				3	313	991												
December							1	323	865									
January				1	322	956												
Average	7	332	942	5	323	957	1	323	865				1	350	1,004			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Alexander:																		
October				1	292	1,023												
November							1	355	883							1	343	991
December																1	339	1,023
January																2	324	931
Average	6	324	963	1	292	1,023	1	355	883							4	335	982
Anson:																		
September				25	295	997				10	352	893	28	339	975	3	352	877
October				22	308	991	2	326	842	1	377	925	43	336	963	1	369	903
November				22	309	985	8	321	896	1	367	893	2	345	1,032	4	345	890
December				9	301	1,013	5	312	890	5	340	903				14	344	912
January				8	300	1,026	5	312	896	3	342	880				29	335	902
Average	250	333	934	86	303	1,002	20	318	881	20	356	899	73	340	990	51	349	897
Ashe:																		
September				1	308	1,016	1	332	940							1	364	887
October							1	313	842							2	318	985
November				1	322	997												
December										1	339	918						
Average	8	330	938	2	315	1,007	2	323	891	1	339	918				3	341	936
Beaufort:																		
October							1	306	909				2	346	918			
December							1	302	912									
Average	4	325	915				2	304	911				2	346	918			

Bertie:																		
October				1	303	959										2	326	940
December							1	293	937									
January							2	322	887									
Average	6	312	937	1	303	959	3	308	912							2	326	940
Bladen:																		
September				3	312	966	1	296	845				5	336	975	1	337	947
October				7	307	1,013	4	273	928	2	356	956	10	337	966	4	333	979
November				8	311	1,010	4	308	950							1	315	994
December				2	314	979	2	309	925	2	326	966				1	318	925
January				3	322	1,026				2	321	922				7	322	953
Average	69	321	958	23	313	999	11	297	912	6	334	948	15	337	971	14	325	960
Buncombe:																		
September							1	319	896				1	333	1,007			
October							1	295	820									
Average	3	320	933				2	307	858				1	333	1,007			
Burke:																		
October													1	332	953	1	342	909
January																1	352	985
Average	3	340	950										1	332	953	2	347	947
Cabarrus:																		
September				2	308	921	1	352	950				8	352	941	2	324	960
October				13	326	944	1	332	972				36	342	925	29	326	979
November				1	292	1,013	1	309	921	1	357	902				21	321	997
December				4	300	979				1	324	903				26	322	991
January				2	306	941	3	292	858	2	340	915				15	324	972
Average	169	327	941	22	306	960	6	321	925	4	340	907	44	347	933	93	323	980
Camden:																		
January				1	296	1,039												
Average	1	296	1,039	1	296	1,039												
Caldwell:																		
January																1	342	918
Average	1	342	918													1	342	918
Carteret:																		
October																1	314	931
November							1	282	940									
January							1	314	903									
Average	3	306	927				2	298	922							1	314	931

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Catawba:																		
October													2	352	915			
November				2	340	912				1	348	868				3	336	988
December										1	321	902						
January																5	326	959
Average	14	340	922	2	340	912				2	335	885	2	352	915	8	331	974
Chatham:																		
September				1	335	1,029				1	341	865				1	348	1,073
October				5	324	1,029				1	352	928	3	336	947	1	324	991
November				1	299	928	5	320	890							1	317	991
December				2	303	1,013	1	307	833	3	325	931						
January				1	322	1,036	2	331	918									
Average	29	328	952	10	317	1,007	8	319	880	5	339	908	3	336	947	3	330	1,018
Cherokee:																		
September							1	318	864									
October													1	358	1,013			
Average	2	338	939				1	318	864				1	358	1,013			
Chowan:																		
September													1	350	887			
October													1	319	960			
November										1	284	998						
Average	3	310	961							1	284	998	2	335	924			

Cleveland:																		
September				5	312	966							1	357	928			
October				2	301	1,016	3	334	833	11	354	865	10	341	883	4	344	950
November				9	326	902	5	325	877	16	345	887	1	356	899	9	334	960
December				2	317	928				6	334	874				5	324	934
January				15	311	915	1	296	814	5	314	826				19	338	941
Average	129	331	900	33	313	945	9	318	841	38	337	863	12	351	903	37	335	946
Columbus:																		
September				1	300	1,070	1	316	906				1	341	953	1	313	1,051
October				7	312	1,071												
November				4	322	1,042												
January				1	326	994												
Average	16	321	989	13	315	1,044	1	316	906				1	341	953	1	313	1,051
Craven:																		
September										1	355	871						
October										1	367	880						
Average	2	361	876							2	361	876						
Cumberland:																		
September				19	301	972	13	306	906				1	318	953	9	321	982
October				19	301	978	26	308	902	3	351	925				2	295	940
November				25	302	960	4	302	931	2	339	918				1	345	1,064
December				14	296	979	1	307	915	2	312	925				1	346	978
January				1	316	934										1	303	972
Average	144	317	948	78	303	965	44	306	914	7	334	923	1	318	953	14	322	987
Currituck:																		
September										2	319	909						
October							2	328	893									
November							1	307	915									
Average	5	319	907				3	318	904	2	319	909						
Davidson:																		
November				1	285	941	6	299	953							3	320	1,048
December				2	309	998	2	291	922							1	333	1,020
January				1	314	979				2	324	880						
Average	18	312	956	4	303	973	8	295	938	2	324	880				4	327	1,034
Davie:																		
October				3	306	925				1	368	855	3	347	922			
November				6	312	979	3	319	864									
December				4	319	963	1	300	865	7	324	868						
January				3	312	950	3	303	925	1	313	852						
Average	35	325	905	16	312	954	7	307	885	9	335	858	3	347	922			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Duplin:																		
September				1	319	1,026												
October				10	313	982	4	317	890									
November				7	323	975	1	349	982									
December							3	318	937									
January				2	334	978	3	311	972									
Average	31	323	968	20	322	990	11	324	945									
Durham:																		
October																1	330	903
November							1	300	883									
Average	2	315	893				1	300	883							1	330	903
Edgecombe:																		
September				7	325	941	1	340	963	2	341	839	6	334	918	11	332	909
October				7	324	953	3	320	909				2	360	1,051	2	340	865
November				4	323	925	1	319	941							1	348	868
December				1	305	864												
Average	48	335	913	19	319	921	5	326	938	2	341	839	8	347	985	14	340	881
Franklin:																		
October				1	358	985												
December							1	344	884									
January							1	332	887									
Average	3	348	936	1	358	985	2	338	886									
Gaston:																		
September				1	304	1,017							7	352	953	1	316	925
October				18	324	963	2	301	925				6	331	940			
November				15	301	944	2	340	896	2	356	868	3	336	997	3	355	994
December				2	299	972	2	306	944	6	337	883				4	337	956
January				5	316	940	3	328	887	2	324	884				3	334	953
Average	87	329	936	41	309	967	9	319	913	10	339	878	16	340	963	11	336	957

Gates:																		
September													2	335	1,042			
October																1	323	874
Average	3	329	958										2	335	1,042	1	323	874
Graham:																		
October				1	339	1,016												
November				1	333	1,007												
Average	2	336	1,012	2	336	1,012												
Granville:																		
September																1	349	877
November																1	318	963
Average	2	334	920													2	334	920
Greene:																		
September										1	353	918	1	374	960			
October													1	333	953			
November				1	339	950				1	351	947						
December							2	303	852									
Average	7	337	923	1	339	950	2	303	852	2	352	933	2	354	957			
Halifax:																		
September				4	332	921	2	326	1,032				2	330	975	1	343	956
October				4	333	877	2	363	906				2	332	1,007			
November				1	325	890	3	343	836	2	348	861						
December							2	301	836									
Average	25	337	921	9	330	896	9	333	903	2	348	861	4	331	991	1	343	956
Harnett:																		
September				15	301	966	2	312	903	4	352	890	2	338	899	3	326	1,017
October				12	311	960	3	311	887	5	335	893	2	336	912	3	326	982
November				14	323	941	6	292	893	1	333	884						
December				7	305	1,004	5	293	906	1	330	931				1	317	940
January				1	313	925	2	304	918									
Average	89	322	929	49	311	959	18	302	901	11	338	900	4	337	906	7	323	980
Haywood:																		
September																1	343	890
October							1	298	842									
Average	2	321	866				1	298	842							1	343	890
Hertford:																		
October							1	335	922									
January				1	318	1,032												
Average	2	327	977	1	318	1,032	1	335	922									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Hoke:																		
September				12	297	978	1	339	858	1	342	871	4	347	1,032	1	321	1,017
October				11	314	988	8	317	874	5	341	861	18	354	978	1	359	1,026
November				17	319	975	10	319	918							6	327	997
December				6	297	972	3	308	928	5	308	906				3	318	947
January				1	302	1,017	5	315	931	4	314	899				5	322	937
Average	127	326	952	47	306	986	27	320	902	15	326	884	22	351	1,005	16	329	985
Iredell:																		
October				1	325	978				2	352	884	1	369	969			
November							1	332	855	1	339	887				1	321	1,013
December										9	329	982						
January										6	335	874				1	335	1,001
Average	23	339	943	1	325	978	1	332	855	18	339	907	1	369	969	2	328	1,007
Johnston:																		
September				15	309	953				8	343	887	1	346	899	5	330	959
October				21	321	953	10	321	925	6	329	855	2	330	906			
November				44	321	928	4	329	884	2	345	903						
December				8	300	906	4	306	918				2	324	941			
January				7	316	940	1	293	921									
Average	140	325	921	95	313	936	19	312	912	16	339	882	5	333	915	5	330	959
Jones:																		
September													1	337	903			
Average	1	337	903										1	337	903			

Lee:																		
September				1	313	1,010	1	333	902	2	370	874	1	339	896	1	333	997
October				4	329	988	4	314	842	1	313	896						
November				3	325	982	3	329	871									
December							1	314	858	1	341	937	1	332	966	1	324	979
January				3	333	969										1	314	887
Average	29	330	928	11	325	987	9	323	868	4	341	902	2	336	931	3	324	954
Lenoir:																		
September										3	328	906						
October				2	311	979	1	318	985	6	346	915	1	323	972			
November				1	327	978	1	314	953	5	329	928	1	331	966			
December							2	298	944									
January				1	331	953	1	285	922				2	340	940	4	325	921
Average	31	323	943	4	323	970	5	304	951	14	334	916	4	331	959	4	325	921
Lincoln:																		
October				6	324	997	1	321	982				1	347	902	2	333	998
November				3	332	937	5	300	928							2	339	959
December				2	318	975	2	368	922	4	336	896				6	331	963
January				2	319	944	2	329	855	2	319	852				6	332	1,001
Average	47	333	928	14	324	963	10	330	922	6	328	874	1	347	902	16	334	980
McDowell:																		
September				1	301	1,042												
October													1	327	1,020			
November							2	329	921									
Average	4	328	994	1	301	1,042	2	329	921				1	327	1,020			
Madison:																		
September				1	313	1,032				1	357	909						
October				1	272	1,061	3	330	899									
November							1	310	912									
December				2	317	1,010				1	332	941						
Average	10	322	955	4	301	1,034	4	320	906	2	345	925						
Martin:																		
September																3	325	902
October																2	327	912
January																1	323	874
Average	6	325	896													6	325	896
Mecklenburg:																		
September				44	305	947	1	336	902	10	356	874	3	332	903	2	324	928
October				59	325	950	17	338	884	18	350	865	14	339	931	1	320	1,020
November				76	330	928	27	332	902	4	333	887	4	335	969	6	344	960
December				58	308	944	4	324	931	9	331	883				5	339	991
January				22	288	928	4	329	861	4	330	883				11	333	921
Average	403	330	922	259	311	939	53	332	896	45	340	878	21	335	934	25	332	964

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Montgomery:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September													1	330	994			
October										1	310	985	4	346	944			
November							3	335	861							1	322	940
December				1	318	1,064				1	337	902				1	332	915
January				1	294	953	1	333	861							2	333	950
Average	17	326	944	2	306	1,009	4	334	861	2	324	944	5	338	969	4	329	935
Moore:																		
October				1	308	1,074	1	384	1,083									
November				2	312	1,115										2	309	997
December							1	318	934									
January							3	313	941	1	314	959				1	301	975
Average	12	317	1,007	3	310	1,095	5	338	986	1	314	959				3	305	986
Macon:																		
September																1	319	982
Average	1	319	982													1	319	982
Nash:																		
September										1	360	903	1	316	1,026			
October				2	333	988	2	311	899							3	327	865
November				3	338	884	2	320	855									
December							1	277	912							1	334	890
January							2	289	960									
Average	18	328	930	5	336	936	7	299	907	1	360	903	1	316	1,026	4	331	878
New Hanover:																		
January																1	342	846
Average	1	342	846													1	342	846

Northampton:																		
September				1	344	1,013							1	330	1,077	2	341	937
October				5	338	922							1	360	972	1	352	899
November				2	344	985	1	317	861									
December										3	339	893	1	332	1,013			
January							2	309	887									
Average	20	336	936	8	342	973	3	313	874	3	339	893	3	341	1,021	3	347	918
Onslow:																		
September										1	351	890						
October										1	333	884						
January																1	358	884
Average	3	350	886							2	342	887				1	358	884
Orange:																		
September																1	331	922
October				3	320	1,042							1	332	1,004			
November				5	316	921	4	325	890									
December							3	298	896	1	318	903						
January				2	297	925	1	331	877							1	328	941
Average	22	322	938	10	311	963	8	318	888	1	318	903	1	332	1,004	2	330	932
Pamlico:																		
October													1	311	706			
Average	1	311	706										1	311	706			
Pasquotank:																		
November							5	314	865	1	361	877						
Average	6	338	871				5	314	865	1	361	877						
Pender:																		
September				1	290	985												
October				5	314	1,013												
November				3	321	1,016												
January				1	293	1,055												
Average	10	305	1,017	10	305	1,017												
Perquimans:																		
October													1	333	928			
November										1	349	937						
December							1	309	944									
Average	3	330	936				1	309	944	1	349	937	1	333	928			
Person:																		
October							1	334	972									
Average	1	334	972				1	334	972									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Pitt:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				1	295	960	1	267	884									
October				3	333	944	1	310	925	1	372	944	1	345	1,035			
November				3	328	944	2	324	941							1	321	925
January				1	324	1,093	2	305	877							6	332	940
Average	23	333	961	8	320	985	6	302	907	1	372	944	1	345	1,035	7	327	933
Randolph:																		
December										1	340	880						
January							1	287	912									
Average	2	313	896				1	287	912	1	340	880						
Richmond:																		
September				8	308	998	2	342	906	3	346	893	6	334	997	2	347	941
October				5	314	1,020	9	333	899				14	345	975			
November				9	311	1,001	8	325	899							2	344	950
December				2	298	966	9	337	934	2	340	918				7	329	893
January				2	295	979	6	323	909	4	335	915				6	330	925
Average	106	331	945	26	305	993	34	332	909	9	340	909	20	340	986	17	338	927
Robeson:																		
September				22	298	988	2	329	937	17	344	909	33	351	953	13	338	956
October				17	301	1,010	32	319	903	20	341	902	54	345	950	23	339	956
November				20	311	1,013	37	320	922	3	348	931				9	333	1,007
December				6	297	985	16	314	940	34	330	921				13	333	972
January				13	294	997	11	308	925	7	312	922				23	325	956
Average	425	327	952	78	300	999	98	318	925	81	335	917	87	348	952	81	334	969

Rockingham:																		
September										1	332	855						
October																1	325	1,077
November																1	327	1,026
January																1	325	944
Average	4	329	936							1	332	855				3	326	1,016
Rowan:																		
October				3	333	956	2	324	890	2	349	896	4	360	921	2	328	979
November				4	314	940	8	342	880	2	339	947						
December				2	315	953	4	318	941	11	331	902						
January				2	317	953	2	293	865	1	338	883				2	316	1,035
Average	51	332	936	11	320	951	16	319	894	16	339	907	4	360	921	4	322	1,007
Rutherford:																		
September				1	293	956												
October				1	317.	950				2	360	846	7	349	884	5	326	972
November				2	345	931	2	338	928	7	343	921				6	326	956
December				1	342	969				5	337	877				2	333	978
January				3	315	937				2	314	883				5	335	997
Average	51	342	924	8	354	949	2	338	928	16	339	882	7	349	884	18	330	976
Sampson:																		
September				6	302	956				3	321	842	1	350	918	1	333	953
October				13	322	982	5	303	909	2	337	912				1	317	1,004
November				8	317	975	3	333	963	2	345	890						
January				2	332	972	1	307	972							1	314	959
Average	49	327	938	29	318	971	9	314	948	7	334	881	1	350	918	3	321	972
Scotland:																		
September				25	295	1,007	2	333	915	11	341	906	30	336	1,004	3	333	940
October				13	303	991	16	315	877	4	334	868	29	339	978	1	347	1,029
November				9	298	1,026	11	322	953	7	336	941	3	341	1,020	3	329	956
December				5	303	1,004	7	311	928	4	325	922				5	321	890
January				16	289	988	2	307	899	9	326	887				1	346	890
Average	216	324	953	68	298	1,003	38	318	914	35	332	905	62	339	1,001	13	335	941
Stanly:																		
September										1	331	823	1	360	969			
October				3	315	1,026				2	347	871	9	336	947	1	327	909
November				1	318	931	5	333	839							1	322	950
December				2	302	998	3	301	864	7	329	865				4	332	963
January				4	302	940	1	293	934	2	332	884				4	338	928
Average	51	326	922	10	309	974	9	309	879	12	335	861	10	348	958	10	330	938

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

NORTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Transylvania:																		
October																1	306	956
Average	1	306	956													1	306	956
Union:																		
September				32	300	994	4	312	921	22	359	909	30	331	969	16	332	887
October				34	321	956	48	322	893	35	348	855	63	330	944	14	320	884
November				38	318	963	45	321	887	19	336	868				23	340	921
December				28	298	969	7	302	858	14	326	858	1	327	861	37	330	883
January				22	302	978	3	299	864	20	315	842	1	330	1,010	29	331	884
Average	585	323	912	154	308	972	107	311	885	110	337	866	95	330	946	119	331	892
Vance:																		
September										1	352	890	2	356	1,001			
October				2	350	922	1	361	865							1	352	909
January							2	313	877									
Average	9	349	919	2	350	922	3	337	871	1	352	890	2	356	1,001	1	352	909
Wake:																		
September				8	316	1,036	3	332	877	1	350	769	3	356	1,013	2	356	975
October				13	326	940	14	342	925				5	329	956			
November				1	289	918	14	335	918	5	352	903				1	324	975
December							4	329	922	5	333	899				4	318	944
January							7	322	912							2	333	922
Average	92	333	934	22	310	965	42	332	911	11	345	857	8	343	985	9	333	954
Warren:																		
October				1	351	909	2	354	877				1	338	918			
November				1	331	934	1	358	827									
December							1	332	807	1	340	871						
January							2	311	839									
Average	10	340	887	2	341	922	6	339	838	1	340	871	1	338	918			

Watauga:																		
October										1	350	953						
December										1	318	884				1	330	925
Average	3	332	922							2	334	919				1	330	925
Wayne:																		
September				18	309	925	1	311	918	9	333	925	2	345	934	2	326	1,058
October				11	325	956	7	315	896	4	353	918						
November				12	327	988	5	321	937	1	347	928						
December							3	308	906				1	337	950			
January				1	339	1,013	2	321	953				1	352	988			
Average	80	331	966	42	325	971	18	315	922	14	344	924	4	345	957	2	326	1,058
Wilkes:																		
September				2	316	963	1	345	922									
October							1	304	887									
November				1	322	1,004	9	318	893									
December							4	318	960									
January				3	299	982												
Average	21	317	950	6	312	983	15	321	916									
Wilson:																		
September				27	324	941	2	319	931	2	317	909	2	338	941	9	330	991
October				24	331	937	7	302	902							5	329	940
November				23	320	937	6	324	906							1	340	975
December							3	312	944				3	323	944	1	338	937
Average	115	324	934	74	325	938	18	314	921	2	317	909	5	331	943	16	334	961
Yadkin:																		
September							1	310	868									
October																3	334	864
January																1	301	937
Average	5	314	885				1	310	868							4	318	901

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

OKLAHOMA.

BY COUNTIES.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	906	286	979	190	258	1,020	207	289	1,001	190	282	985	136	309	939	183	299	991
Atoka	5	297	937	1	276		1	298	988				3	316	886			
Beckham	14	302	976	9	285	1,050	2	301	988	2	281	964	1	340	903			
Blaine	22	294	997	1	277	1,040							5	304	951	16	302	1,001
Bryan	24	280	932	2	271	974	16	275	951	2	275	977	2	317	912	2	263	846
Caddo	75	283	1,008	23	257	1,038	17	280	1,014	20	273	987	8	303	976	7	300	1,027
Canadian	1	276		1	276													
Carter	31	284	980	3	260	1,034	20	290	1,036	7	275	1,020	1	310	831			
Cherokee	8	290	945	2	241	1,023	1	307	1,000				5	322	812			
Choctaw	7	287	920	4	286					2	261	896	1	314	943			
Cleveland	8	300	963	5	263	931	1	284	986	1	321	967	1	330	967			
Coal	8	279	995	2	265	905	2	281	1,005	3	278	1,053	1	290	1,015			
Comanche	46	275	1,031	5	240	1,065	8	281	1,046	2	263	1,034	10	299	977	21	291	1,033
Cotton	14	274	1,057	4	242	1,078	4	266	1,121				2	292	1,005	4	297	1,024
Creek	5	291	957	1	244	983				2	309	979	2	321	909			
Custer	20	286	1,061	1	235	1,133				1	288	1,059	4	315	1,015	14	304	1,037
Garvin	36	265	991	6	239	1,021	4	243	996	20	256	968	5	298	977	1	290	
Grady	35	281	1,004	9	251	1,040	5	268	983	11	272	989	3	318	1,000	7	294	1,006
Greer	43	290	1,017	12	268	1,066	10	272	981	5	291	992	5	315	1,022	11	305	1,026
Harmon	29	302	1,030	11	268	1,067	2	317	1,036	4	330	995	3	299	1,009	9	296	1,042
Haskell	7	276	927	2	259	941	2	269	983				3	299	858			
Hughes	9	259	931	2	251	920	1	264	955	6	261	918						
Jackson	50	298	1,011				9	283	1,007	8	298	1,019	12	311	985	21	299	1,031
Jefferson	25	279	1,021	2	237	1,050	7	265	1,005	11	287	1,034	3	309	995	2	299	1,020
Johnston	10	292	1,004				5	300	1,062	2	261	1,015	3	316	935			
Kingfisher	3	331	947				2	326	998				1	336	896			

Kiowa	79	288	1,028	6	250	1,039	14	292	1,026	23	289	1,010	1	309	1,021	35	298	1,043
Le Flore	12	290	947	3	263	937	3	325	965	1	264	998	5	308	886			
Lincoln	22	307	973	13	271	1,011	3	304	1,010	5	310	935	1	343	934			
Logan	12	286	999	3	265	1,007	2	290	1,017	5	300	980	2	287	993			
Love	8	295	946				4	296	979	1	288	955	3	300	904			
McClain	22	281	979	9	251	1,016	9	288	1,004	1	274	922	3	309	973			
McCurtain	6	287	930	2	298	926	4	275	934									
McIntosh	10	286	936	4	253	979	2	285	953	2	288	983	1	301	882	1	305	884
Marshall	6	280	922	1	260	939	3	268	872	1	308	939	1	282	939			
Mayes	2	247	1,074	2	247	1,074												
Murray	6	271	983	1	233	1,050	1	253	974	1	287		3	309	924			
Muskogee	15	302	942	6	256	1,036	3	308	973	1	296	998	4	305	828	1	345	874
Noble	1	257	983							1	257	983						
Okfuskee	13	290	970	7	276	1,010	3	300	1,018	2	265	888	1	320	962			
Oklahoma	9	298	960	4	265		1	314	986	2	308		2	304	933			
Okmulgee	5	284	947	2	243	910	1	313	1,045	1	276		1	302	886			
Pawnee	2	268	926	1	257	891				1	278	960						
Payne	6	256	992	3	260	1,007	1	259	1,034	2	249	934						
Pittsburg	8	292	927	1	268	934							7	316	920			
Pontotoc	10	292	944				1	269	939	5	298	965	4	310	928			
Pottawatomie	4	317	995				1	352	1,034	2	290	967				1	309	983
Pushmataha	1	305	839										1	305	839			
Seminole	2	258								1	234					1	281	
Sequoyah	7	308	937				3	309	969	2	275	989	1	327	867	1	322	922
Stephens	50	284	1,016	9	245	1,061	10	284	1,021	15	302	995	4	299	983	12	289	1,022
Texas	1	285	998										1	285	998			
Tillman	30	282	1,049	1	231	1,057	4	291	1,101	4	279	1,036	6	312	1,018	15	297	1,035
Tulsa	2	269	1,059	2	269	1,059												
Wagoner	7	291	1,043				6	284	1,055	1	298	1,031						
Woods	1	289	939				1	289	939									
Washita	12	282	1,052	2	260	1,097	8	306	1,053	1	270	1,078				1	291	981

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

OKLAHOMA—Continued.

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Atoka:																		
October													1	307	846			
November													1	328	896			
December													1	312	915			
January				1	276		1	298	988									
Average	5	297	937	1	276		1	298	988				3	316	886			
Beckham:																		
September				4	275	1,112				1	258							
October				1	284	1,045	1	328	1,036				1	340	903			
December				3	288	1,017	1	274	939									
January				1	293	1,026				1	303	964						
Average	14	302	976	9	285	1,050	2	301	988	2	281	964	1	340	903			
Blaine:																		
September													1	303	955	3	313	998
October													1	294	884	5	291	1,002
November													2	301	964	6	296	1,005
December				1	277	1,040										2	306	998
January													1	319	1,000			
Average	22	294	997	1	277	1,040							5	304	951	16	302	1,001
Bryan:																		
September				1	266	974	4	240	960	2	275	977				2	263	846
October							1	262	1,000									
November							8	299	941									
December				1	275		1	281	922									
January							2	293	931				2	317	912			
Average	24	280	932	2	271	974	16	275	951	2	275	977	2	317	912	2	263	846

Caddo:																		
September				7	266	1,064	3	287	1,091	7	260	1,019				1	285	1,078
October				2	249	1,018	3	291	1,057	4	290	1,015				3	312	1,038
November				4	261	1,048	6	290	1,040	3	254	962						
December				7	259	1,031	3	287	969	5	265	988	2	297	996			
January				3	248	1,031	2	246	912	1	295	953	6	308	955	3	304	964
Average	75	283	1,008	23	257	1,038	17	280	1,014	20	273	987	8	303	976	7	300	1,027
Canadian:																		
October				1	276													
Average	1	276		1	276													
Carter:																		
September				1	248	1,031	12	293	1,048	1	260	1,057						
October							6	282	1,005									
December				2	272	1,036	2	295	1,055	3	276	1,012	1	310	831			
January										3	288	991						
Average	31	284	980	3	260	1,034	20	290	1,036	7	275	1,020	1	310	831			
Cherokee:																		
September				1	234	988							1	331	765			
October				1	247	1,057	1	307	1,000									
December													4	312	858			
Average	8	290	945	2	241	1,023	1	307	1,000				5	322	812			
Choctaw:																		
September				4	286					1	232							
October										1	289	896						
November													1	314	943			
Average	7	287	920	4	286					2	261	896	1	314	943			
Cleveland:																		
September				5	263	931												
October										1	321	967						
November							1	284	986									
December													1	330	967			
Average	8	300	963	5	263	931	1	284	986	1	321	967	1	330	967			
Coal:																		
October							2	281	1,005	2	303	1,036						
November				2	265	915							1	290	1,015			
December										1	252	1,069						
Average	8	279	995	2	265	905	2	281	1 005	3	278	1,053	1	290	1,015			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

OKLAHOMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Comanche:																		
September				2	235	1,074	1	292	1,116	1	241					4	288	1,062
October				2	238	1,072	5	289	1,069				1	310	986	5	290	1,040
November							1	242	924	1	284	1,034	3	300	1,045	2	298	1,043
December				1	248	1,048							5	308	974	3	286	1,007
January							1	300	1,074				1	279	903	7	292	1,012
Average	46	275	1,031	5	240	1,065	8	281	1,046	2	263	1,034	10	299	977	21	291	1,033
Cotton:																		
September																1	282	1,021
October				2	240	1,093	4	266	1,121				1	295	1,017	1	314	1,034
November				1	249													
December				1	238	1,062												
January													1	289	993	2	296	1,018
Average	14	274	1,057	4	242	1,078	4	266	1,121				2	292	1,005	4	297	1,024
Creek:																		
September				1	244	983												
October										2	309	979	1	304	879			
November													1	338	939			
Average	5	291	957	1	244	983				2	309	979	2	321	909			
Custer:																		
September				1	235	1,133										2	305	1,076
October										1	288	1,059				5	310	1,053
November													2	328	1,010	2	312	1,057
December													1	315	1,050	3	290	969
January													1	302	986	2	305	1,031
Average	20	286	1,061	1	235	1,133				1	288	1,059	4	315	1,015	14	304	1,037

Garvin:																		
September				4	239	1,055	2	221	953	10	248	991						
October							2	265	1,038				2	301	977			
November													3	294	977	1	290	
December				2	239	986				7	265	955						
January										3	254	958						
Average	36	265	991	6	239	1,021	4	243	996	20	256	968	5	298	977	1	290	
Grady:																		
September				4	245	1,064				3	276	1,000						
October				1	251	1,036	4	283	1,064				2	301	983	2	286	1,002
November										2	276	1,005				1	293	974
December				4	256	1,019										3	295	1,012
January							1	252	901	6	264	962	1	335	1,017	1	303	1,036
Average	35	281	1,004	9	251	1,040	5	268	983	11	272	989	3	318	1,000	7	294	1,006
Greer:																		
September				3	256	1,093				2	277	986	1	335	1,062	1	311	1,059
October				5	259	1,112	1	299	1,088				2	282	1,015	4	304	1,048
November				1	266	1,074	6	276	962	2	314	1,069				2	306	1,036
December				2	276	1,015	2	259	969	1	281	922	2	329	988	1	304	950
January				1	284	1,036	1	254	905							3	298	1,036
Average	43	290	1,017	12	268	1,066	10	272	981	5	291	992	5	315	1,022	11	305	1,026
Harmon:																		
September				1	256	1,150				1	337	1,007				1	304	1,069
October				4	260	1,116	1	324	1,034	2	317	953	1	302	1,086			
November				1	290	1,067	1	309	1,038	1	337	1,026				4	301	1,019
December				4	276	1,021										3	301	993
January				1	256	979							2	296	931	1	277	1,086
Average	29	302	1,030	11	268	1,067	2	317	1,036	4	330	995	3	299	1,009	9	296	1,042
Haskell:																		
September				2	259	941							3	299	858			
November							2	269	983									
Average	7	276	927	2	259	941	2	269	983				3	299	858			
Hughes:																		
September				1	263					5	251	888						
October				1	238	920	1	264	955									
November										1	270	948						
Average	9	259	931	2	251	920	1	264	955	6	261	918						

TABLE VI.—*Yields of oil and meal, by counties, as compiled by analyses*—Continued.

OKLAHOMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Jackson:																		
September							1	247	926	3	274	1,034						
October							2	293	1,069	1	293	1,031	7	302	986	6	298	1,045
November							3	315	1,040				2	318	977	9	303	1,040
December							3	276	993	3	292	983				6	297	1,007
January										1	332	1,029	3	312	993			
Average	50	298	1,011				9	283	1,007	8	298	1,019	12	311	985	21	299	1,031
Jefferson:																		
September				1	237	1,026				4	278	1,053						
October							5	264	1,050	1	300		2	307	1,010	1	295	1,015
November							2	265	960	1	294	1,074						
December				1	236	1,074				2	282	1,015	1	310	979			
January										3	283	993				1	303	1,024
Average	25	279	1,021	2	237	1,050	7	265	1,005	11	287	1,034	3	309	995	2	299	1,020
Johnston:																		
September							5	300	1,062	1	264							
November													1	329	1,015			
December													2	303	855			
January										1	257	1,015						
Average	10	292	1,004				5	300	1,062	2	261	1,015	3	316	935			
Kingfisher:																		
October							1	328	1,010									
November							1	323	986									
December													1	336	896			
Average	3	331	947				2	326	998				1	336	896			

Kiowa:																		
September				3	244	1,043				10	270	1,055				4	298	1,031
October				2	258	1,088	2	290	1,040	5	300	1,040	1	309	1,021	11	303	1,057
November				1	252	955	6	316	1,064							5	303	1,081
December							4	282	993	7	285	955				8	292	1,029
January							2	280	1,007	1	302	991				7	292	1,019
Average	79	288	1,028	6	250	1,039	14	292	1,026	23	289	1,010	1	309	1,021	35	298	1,043
Le Flore:																		
September				2	262	931	2	315	977				5	308	886			
October				1	263	943												
December							1	335	953									
January										1	264	998						
Average	12	290	947	3	263	937	3	325	965	1	264	998	5	308	886			
Lincoln:																		
September				7	259	1,024				3	254	879						
October				4	270		3	304	1,010				1	343	934			
December				2	283	998				1	378	943						
January										1	299	983						
Average	22	307	973	13	271	1,011	3	304	1,010	5	310	935	1	343	934			
Logan:																		
September				1	240					4	304	945	1	290	1,002			
October				1	289								1	284	983			
November							2	290	1,017									
December				1		1,007												
January										1	295	1,015						
Average	12	286	999	3	265	1,007	2	290	1,017	5	300	980	2	287	993			
Love:																		
September							2	310	1,050	1	288	953						
November							1	307	1,086									
December													2	308	869			
January							1	271	891				1	292	939			
Average	8	295	946				4	296	979	1	288	953	3	300	904			
McClain:																		
September				2	250	988												
October							2	301	1,069									
November							2	309	1,007				1	301	974			
December				7	252	1,043	3	288	1,002	1	274	922	2	316	972			
January							2	253	939									
Average	22	281	979	9	251	1,016	9	288	1,004	1	274	922	3	309	973			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

OKLAHOMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
McCurtain:																		
September				1	289		2	239										
November				1	306	926												
December							2	310	934									
Average	6	287	930	2	298	926	4	275	934									
McIntosh:																		
September				1	256	960				1	278	1,040	1	301	882			
October				3	250	998	1	261	860							1	305	884
November							1	308	1,045	1	297	926						
Average	10	286	936	4	253	979	2	285	953	2	288	983	1	301	882	1	305	884
Marshall:																		
September										1	308	939						
October													1	282	939			
November							1	259	872									
December							2	277										
January				1	260	939												
Average	6	280	922	1	260	939	3	268	872	1	308	939	1	282	939			
Mayes:																		
October				2	247	1,074												
Average	2	247	1,074	2	247	1,074												
Murray:																		
September				1	233	1,050				1	287							
November							1	253	974				1	311	950			
December													2	307	898			
Average	6	271	983	1	233	1,050	1	253	974	1	287		3	309	924			

Muskogee:																		
September				4	255	1,019							3	308	831	1	345	874
October				2	256	1,057				1	296	998						
November							1	321	1,010									
December													1	301	825			
January							2	294	936									
Average	15	302	942	6	256	1,036	3	308	973	1	296	998	4	305	828	1	345	874
Noble:																		
September										1	257	983						
Average	1	257	983							1	257	983						
Okfuskee:																		
September				5	249	1,042				2	265	888						
October				1	276		1	290	1,059				1	320	962			
November							2	310	977									
December				1	302	1,007												
Average	13	290	970	7	276	1,010	3	300	1,018	2	265	888	1	320	962			
Oklahoma:																		
September				1	276					2	308							
October				3	254													
November							1	314	986				1	299	977			
December													1	309	888			
Average	9	298	960	4	265		1	314	986	2	308		2	304	933			
Okmulgee:																		
September										1	276		1	302	886			
October				2	243	910												
November							1	313	1,045									
Average	5	284	947	2	243	910	1	313	1,045	1	276		1	302	886			
Pawnee:																		
September				1	257	891												
October										1	278	960						
Average	2	268	926	1	257	891				1	278	960						
Payne:																		
September				3	260	1,007				2	249	934						
November							1	259	1,034									
Average	6	256	992	3	260	1,007	1	259	1,034	2	249	934						
Pittsburgh:																		
September				1	268	934							4	309	886			
November													2	312	939			
January													1	328	936			
Average	8	292	927	1	268	934							7	316	920			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

OKLAHOMA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Pontotoc:																		
September										2	306	929	1	305	1,000			
October										1	294							
November							1	269	939				1	333	912			
December										2	295	1,000						
January													2	293	872			
Average	10	292	944				1	269	939	5	298	965	4	310	928			
Pottawatomie:																		
September										1	266							
October																1	309	983
November							1	352	1,034	1	314	967						
Average	4	317	995				1	352	1,034	2	290	967				1	309	983
Pushmataha:																		
September													1	305	839			
Average	1	305	839										1	305	839			
Seminole:																		
September										1	234							
October																1	281	
Average	2	258								1	234					1	281	
Sequoyah:																		
September													1	327	867			
October							1	321	1,015	1	240	1,017						
November							2	297	922									
December										1	310	960						
January																1	322	922
Average	7	308	937				3	309	969	2	275	989	1	327	867	1	322	922

Stephens:																		
September				5	238	1,062	1	297		3	278	1,015				1	276	1,083
October							3	288	1,083	3	281	967	1	297	986	7	290	1,015
November							2	287	1,007				1	285	1,017	3	295	1,026
December				4	252	1,059	2	282	1,017	5	277	981	2	316	945			
January							2	264	977	4	270	1,015				1	294	964
Average	50	279	1,016	9	245	1,061	10	284	1,021	15	277	995	4	299	983	12	289	1,022
Texas:																		
October													1	285	998			
Average	1	285	998										1	285	998			
Tillman:																		
September				1	231	1,057				2	281	1,074						
October							2	279	1,135	1	258	1,072	3	301	1,034	6	294	1,031
November							1	280	1,124				2	279	1,043	1	295	1,078
December							1	314	1,043				1	355	977	7	298	1,015
January										1	297	962				1	300	1,017
Average	30	282	1,049	1	231	1,057	4	291	1,101	4	279	1,036	6	312	1,018	15	297	1,035
Tulsa:																		
October				1	231	1,059												
December				1	306													
Average	2	269	1,059	2	269	1,059												
Wagoner:																		
November										1	298	1,031						
January							6	284	1,055									
Average	7	291	1,043				6	284	1,055	1	298	1,031						
Woods:																		
November							1	289	939									
Average	1	289	939				1	289	939									
Washita:																		
September				2	260	1,097				1	270	1,078						
October							3	309	1,069							1	291	981
November							3	293	1,038									
December							1	316	1,067									
January							1	306	1,036									
Average	12	282	1,052	2	260	1,097	8	306	1,053	1	270	1,078				1	291	981

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

SOUTH CAROLINA.

BY COUNTIES.

County.	Total samples.	5-year average, yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	9,277	327	941	1,762	306	979	1,794	321	938	1,029	333	911	1,737	336	961	2,955	337	922
Abbeville	162	318	933	61	297	939	12	317	928	35	332	878	22	323	962	32	322	959
Aiken	324	329	961	89	298	1,002	18	328	970	64	333	928	50	345	976	103	339	931
Anderson	141	327	915	34	311	944	27	330	894	17	331	885	22	335	934	41	330	918
Bamberg	155	319	953	34	293	994	39	305	954	15	326	938	21	323	979	46	346	902
Barnwell	743	324	941	191	303	967	32	321	975	131	330	915	97	323	954	292	345	895
Beaufort	80	322	955	24	307	1,035	35	317	963	3	325	915	3	317	961	15	346	900
Berkeley	196	328	951	39	299	979	73	319	952	5	348	933	23	332	998	56	340	894
Calhoun	119	333	943	42	303	953	28	321	944	8	333	926	8	353	987	33	355	903
Charleston	171	329	941	65	309	1,010	42	315	957	1	341	871	15	342	965	48	338	901
Cherokee	11	332	923	2	328	950	.....	.....	.....	6	331	921	3	337	899	.....	.....	.....
Chester	212	332	950	15	315	981	12	324	950	25	340	903	69	344	982	91	339	935
Chesterfield	148	326	942	29	296	1,027	12	319	910	10	347	928	43	330	976	54	340	871
Clarendon	309	328	939	48	311	973	75	320	933	53	337	923	37	334	962	96	338	906
Colleton	259	321	952	32	296	1,000	139	313	965	5	322	920	25	333	954	58	339	919
Darlington	430	313	938	91	299	972	160	310	938	63	317	906	57	315	941	59	323	935
Dillon	321	325	946	31	294	1,003	44	320	925	13	327	868	110	348	957	123	335	978
Dorchester	218	325	956	35	300	1,008	80	317	969	9	331	953	27	331	956	67	344	895
Edgefield	100	325	955	31	305	991	12	329	951	25	333	915	14	328	969	18	332	951
Fairfield	106	338	924	29	315	930	13	340	908	22	345	920	28	349	973	14	342	886
Florence	333	320	928	37	302	977	99	310	903	50	322	909	38	333	919	109	331	930
Georgetown	55	322	957	7	287	977	12	315	938	3	329	963	9	343	1,005	24	338	903
Greenville	90	333	934	24	315	951	9	339	943	17	336	883	26	345	942	14	330	949
Greenwood	271	325	944	48	309	951	10	322	934	23	332	903	74	335	978	116	329	956
Hampton	258	325	951	77	301	1,012	93	314	965	25	331	915	22	331	960	41	349	903
Horry	34	326	932	6	306	1,013	15	315	929	2	332	868	3	341	925	8	334	927

Jasper	28	320	954	16	296	1,008	1	297	915	1	336	956	4	337	1,006	6	336	883
Kershaw	112	334	955	15	308	1,014	9	327	958	10	351	896	35	344	995	43	339	913
Lancaster	51	330	921	4	307	967	1	312	906	3	344	878	16	341	955	27	344	897
Laurens	281	332	930	49	318	959	16	324	947	25	341	887	69	338	920	122	338	938
Lee	176	321	938	17	304	975	50	315	932	16	321	904	34	331	966	59	332	914
Lexington	176	327	949	52	302	1,018	29	328	966	8	332	890	37	337	957	50	338	915
McCormick	181	331	941	.....	.....	.....	4	332	963	47	335	887	67	331	972	63	326	943
Marion	106	326	959	24	293	995	23	319	920	2	332	906	26	346	963	31	340	1,011
Marlboro	587	330	965	65	303	1,009	79	328	948	24	335	925	181	346	987	238	338	958
Newberry	193	329	930	36	310	954	10	338	946	4	320	889	24	340	945	119	335	917
Oconee	7	332	953	1	305	950	1	359	963	3	335	913	1	346	1,001	1	315	937
Orangeburg	491	325	953	113	293	978	135	312	944	36	331	944	73	343	995	134	348	903
Pickens	20	337	899	13	335	914	3	347	909	3	329	841	1	336	931	.....	.....	.....
Richland	264	328	942	52	304	973	44	323	958	37	332	930	51	339	956	80	341	894
Saluda	62	321	970	10	297	1,035	10	310	965	4	337	938	10	325	960	28	336	953
Spartanburg	104	331	927	16	318	947	7	317	917	23	341	903	19	340	925	39	337	943
Sumter	536	327	949	56	319	991	134	316	948	104	331	924	78	336	972	164	333	912
Union	124	333	917	25	318	936	32	326	901	16	347	901	26	342	927	25	334	918
Williamsburg	330	311	918	55	294	954	94	296	911	7	310	884	73	317	939	101	340	903
York	202	331	921	22	320	970	21	315	865	26	337	898	66	346	946	67	337	926

By Counties and Months.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Abbeville:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September	.....	.....	.....	10	295	922	3	311	918	16	342	852	7	333	963	9	333	979
October	.....	.....	.....	7	295	972	.....	.....	.....	7	338	855	10	333	925	8	320	937
November	.....	.....	.....	18	299	915	5	321	931	3	339	909	4	314	963	7	315	940
December	.....	.....	.....	12	295	928	3	328	931	4	313	874	.....	.....	.....	6	324	975
January	.....	.....	.....	14	299	956	1	309	931	5	330	902	1	311	998	2	319	963
Average	162	318	933	61	297	939	12	317	928	35	332	878	22	323	962	32	322	959

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—**Continued.**

SOUTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Aiken:																		
September	.....	.....	.....	25	308	985	2	335	966	7	346	902	12	335	950	20	343	928
October	.....	.....	.....	14	297	1,020	1	333	991	19	340	922	35	341	978	24	338	928
November	.....	.....	.....	23	303	1,004	5	328	985	19	336	921	1	359	1,007	18	335	950
December	.....	.....	.....	11	287	985	4	331	950	13	324	937	1	349	947	24	341	922
January	.....	.....	.....	16	296	1,016	6	312	956	6	319	959	1	340	997	17	338	928
Average	324	329	961	89	298	1,002	18	328	970	64	333	928	50	345	976	103	339	931
Anderson:																		
September	.....	.....	.....	4	292	928	.....	.....	.....	8	339	871	9	342	940	7	332	918
October	.....	.....	.....	7	315	959	9	314	890	3	319	984	11	334	896	12	330	937
November	.....	.....	.....	12	311	953	16	332	902	3	346	871	.....	.....	.....	7	329	909
December	.....	.....	.....	3	308	960	1	325	874	2	312	915	1	341	918	10	336	937
January	.....	.....	.....	8	327	922	1	347	909	1	337	884	1	324	982	5	324	887
Average	141	327	915	34	311	944	27	330	894	17	331	885	22	335	934	41	330	918
Bamberg:																		
September	.....	.....	.....	16	286	969	2	314	941	10	340	947	13	334	950	14	340	871
October	.....	.....	.....	6	295	972	17	310	940	3	319	953	7	327	994	15	346	874
November	.....	.....	.....	3	300	1,010	8	300	947	.....	.....	.....	1	309	994	12	346	909
December	.....	.....	.....	2	297	1,029	7	294	991	1	309	893	.....	.....	.....	1	346	937
January	.....	.....	.....	7	286	991	5	308	950	1	335	960	.....	.....	.....	4	341	918
Average	155	319	953	34	293	994	39	305	954	15	326	938	21	323	979	46	346	902
Barnwell:																		
September	.....	.....	.....	42	309	937	9	327	950	27	340	906	35	340	934	54	349	880
October	.....	.....	.....	21	303	963	6	328	978	43	336	899	57	337	944	38	348	877
November	.....	.....	.....	57	300	966	7	325	963	22	320	937	4	318	982	78	342	903
December	.....	.....	.....	23	302	978	6	320	966	20	326	922	.....	.....	.....	56	342	906
January	.....	.....	.....	48	303	991	4	304	1,010	19	327	922	1	298	956	66	345	909
Average	743	324	941	191	303	967	32	321	975	131	330	915	97	323	954	292	345	895

Beaufort:																		
September				6	298	1,020	2	322	915	1	336	874				3	339	861
October				2	291	1,020	8	322	956				2	336	925	5	352	883
November				5	308	1,036	9	318	969							5	347	937
December				4	314	1,058	10	308	998				1	298	997			
January				7	323	1,042	6	314	975	2	314	956				2	344	918
Average	80	322	955	24	307	1,035	35	317	963	3	325	915	3	317	961	15	346	900
Berkeley:																		
September				4	286	950	3	336	963	1	356	941	5	333	979	1	339	849
October				12	307	982	17	322	922				17	330	979	14	353	890
November				12	304	985	16	317	956				1	333	1,036	17	336	909
December				4	298	972	18	311	960	4	340	925				5	336	903
January				7	299	1,004	19	311	959							19	338	921
Average	196	328	951	39	299	979	73	319	952	5	348	933	23	332	998	56	340	894
Calhoun:																		
September				13	302	909	6	326	896	4	344	915	4	350	982	13	354	899
October				17	306	966	13	317	979				4	355	991	8	358	861
November				10	306	982	7	315	931							9	351	909
December				2	299	953	1	325	969	4	322	937						
January							1	322	944							3	357	941
Average	119	333	943	42	303	953	28	321	944	8	333	926	8	353	987	33	355	903
Charleston:																		
September				5	302	1,007	2	314	991				4	348	950	3	345	849
October				16	314	959	17	322	912				11	335	979	21	340	884
November				13	320	1,020	14	327	953							17	337	912
December				9	307	1,067	5	303	969	1	341	871				2	347	940
January				22	301	998	4	309	960							5	321	922
Average	171	329	941	65	309	1,010	42	315	957	1	341	871	15	342	965	48	338	901
Cherokee:																		
October										2	348	884	3	337	899			
November				1	331	921												
December										3	317	899						
January				1	325	978				1	327	979						
Average	11	332	923	2	328	950				6	331	921	3	337	899			
Chester:																		
September				8	308	972	2	333	1,020	7	340	899	23	353	979	15	340	922
October							3	314	934	6	351	893	43	339	972	28	338	944
November				6	319	940	7	325	896	5	336	909	3	340	994	25	340	950
December				1	319	1,032				7	333	909				16	345	937
January																7	333	921
Average	212	332	950	15	315	981	12	324	950	25	340	903	69	344	982	91	339	935

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

SOUTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Chesterfield:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				12	295	1,032	4	321	906	8	337	934	20	337	982	17	342	858
October				5	300	1,013	6	326	880	2	356	921	21	329	960	13	336	874
November				6	301	1,045							2	325	985	7	346	890
December							2	309	944							9	341	874
January				6	286	1,017										8	336	861
Average	148	326	942	29	296	1,027	12	319	910	10	347	928	43	330	976	54	340	871
Clarendon:																		
September				8	311	941	11	330	918	15	347	931	18	331	985	19	348	899
October				11	312	978	22	319	921	11	340	918	18	338	985	34	345	903
November				19	310	979	23	314	947	9	338	921				11	335	921
December				6	310	1,001	7	322	925	11	330	912	1	333	915	17	334	903
January				4	312	966	12	316	956	7	330	934				15	328	906
Average	309	328	939	48	311	973	75	320	933	53	337	923	37	334	962	96	338	906
Colleton:																		
September				16	295	982	9	314	950	1	319	906	6	333	937	13	342	931
October				4	291	1,013	33	315	950	1	351	826	18	337	975	17	336	893
November				4	300	1,036	32	316	966	2	305	959	1	328	950	11	339	934
December				3	301	1,004	35	308	988							8	341	921
January				5	293	966	30	311	969	1	313	988				9	335	915
Average	259	321	952	32	296	1,000	139	313	965	5	322	920	25	333	954	58	339	919
Darlington:																		
September				21	304	959	19	312	902	9	334	925	22	313	941	12	323	985
October				16	282	956	38	307	940	22	325	896	29	324	953	15	321	915
November				20	304	966	38	315	950	24	320	922	4	320	959	5	324	966
December				16	300	991	35	306	956	6	317	922	1	307	956	8	319	921
January				18	305	988	30	311	940	2	287	865	1	312	896	19	326	890
Average	430	313	938	91	299	972	160	310	938	63	317	906	57	315	941	59	323	935

Dillon:																		
September	.....	.....	.....	14	288	1,010	19	306	864	13	327	969	40	346	960	44	345	991
October	.....	.....	.....	5	298	1,001	13	328	934	.....	.....	.....	70	349	953	50	335	988
November	.....	.....	.....	10	293	1,007	8	325	944	.....	.....	.....	.....	.....	.....	16	339	975
December	.....	.....	.....	2	296	994	2	320	934	.....	.....	.....	.....	.....	.....	9	327	966
January	.....	.....	.....	.....	.....	.....	2	323	947	.....	.....	.....	.....	.....	.....	4	329	972
Average	321	325	946	31	294	1,003	44	320	925	13	327	868	110	348	957	123	335	978
Dorchester:																		
September	.....	.....	.....	7	292	963	10	332	966	.....	.....	.....	6	332	934	8	347	884
October	.....	.....	.....	15	309	1,026	23	327	947	4	334	940	21	329	978	24	345	884
November	.....	.....	.....	10	299	991	20	321	978	3	325	956	.....	.....	.....	18	344	909
December	.....	.....	.....	1	309	1,016	21	310	978	2	333	963	.....	.....	.....	7	345	890
January	.....	.....	.....	2	291	1,045	6	297	975	.....	.....	.....	.....	.....	.....	10	340	906
Average	218	325	956	35	300	1,008	80	317	969	9	331	953	27	331	956	67	344	895
Edgefield:																		
September	.....	.....	.....	8	308	944	1	350	925	9	347	887	4	346	966	4	340	906
October	.....	.....	.....	1	313	918	2	321	963	10	333	921	8	332	934	5	326	915
November	.....	.....	.....	11	299	1,017	3	338	963	2	310	915	1	333	978	5	333	966
December	.....	.....	.....	3	294	1,058	3	326	959	2	338	925	.....	.....	.....	1	323	1,042
January	.....	.....	.....	8	309	1,020	3	310	944	2	337	925	1	302	997	3	339	928
Average	100	325	955	31	305	991	12	329	951	25	333	915	14	328	969	18	332	951
Fairfield:																		
September	.....	.....	.....	12	313	918	2	358	890	3	344	906	12	345	966	3	327	833
October	.....	.....	.....	3	336	985	5	333	950	15	340	944	16	352	979	4	349	864
November	.....	.....	.....	6	317	944	4	341	921	2	359	947	.....	.....	.....	3	352	950
December	.....	.....	.....	6	310	928	1	320	909	2	337	884	.....	.....	.....	2	346	877
January	.....	.....	.....	2	297	877	1	349	868	.....	.....	.....	.....	.....	.....	2	334	906
Average	106	338	924	29	315	930	13	340	908	22	345	920	28	349	973	14	342	886
Florence:																		
September	.....	.....	.....	5	306	975	2	312	884	.....	.....	.....	3	330	887	11	333	950
October	.....	.....	.....	13	306	979	25	316	899	14	330	883	34	333	918	33	331	921
November	.....	.....	.....	10	298	966	30	312	884	17	324	921	1	335	953	13	331	922
December	.....	.....	.....	2	303	988	15	301	918	16	305	909	.....	.....	.....	26	333	922
January	.....	.....	.....	7	299	979	27	310	928	3	328	922	.....	.....	.....	26	328	934
Average	333	320	928	37	302	977	99	310	903	50	322	909	38	333	919	109	331	930
Georgetown:																		
September	.....	.....	.....	1	298	956	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	339	890
October	.....	.....	.....	1	268	997	3	321	940	.....	.....	.....	8	328	959	10	339	893
November	.....	.....	.....	2	286	1,010	.....	.....	.....	.....	.....	.....	1	358	1,051	4	339	925
December	.....	.....	.....	1	295	922	4	309	966	2	341	921	.....	.....	.....	2	327	902
January	.....	.....	.....	2	290	1,001	5	315	909	1	316	1,004	.....	.....	.....	6	345	903
Average	55	322	957	7	287	977	12	315	938	3	329	963	9	343	1,005	24	338	903

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

SOUTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Greenville:																		
September				7	296	979	1	333	903				10	348	928	3	331	937
October				7	328	934	1	340	925	17	336	883	13	338	915	3	341	940
November							3	360	896				1	344	922	4	333	972
December				2	321	950	3	327	1,004				2	351	1,001	2	324	940
January				8	316	940	1	335	988							2	323	956
Average	90	333	934	24	315	951	9	339	943	17	336	883	26	345	942	14	330	949
Greenwood:																		
September				14	307	975	2	323	944	10	345	865	45	347	978	14	340	947
October				6	312	940	4	323	937				17	333	960	39	324	960
November				12	310	950	4	320	921	2	334	950	5	339	972	47	333	963
December				7	310	925				5	320	896	5	333	1,001	12	327	950
January				9	307	963				6	329	902	2	325	978	4	323	959
Average	271	325	944	48	309	951	10	322	934	23	332	903	74	345	978	116	329	956
Hampton:																		
September				12	296	978	16	324	940	10	350	912	14	337	959	11	358	883
October				8	301	1,035	18	320	944	4	337	918	7	339	941	3	359	909
November				28	317	997	24	319	982	3	331	906	1	318	979	7	341	906
December				15	295	1,029	20	301	982	5	314	912				9	343	909
January				14	298	1,023	15	306	979	3	323	925				11	343	909
Average	258	325	951	77	301	1,012	93	314	965	25	331	915	22	331	960	41	349	903
Horry:																		
September							1	334	959							2	364	842
October				2	303	1,032	2	316	893				3	341	925	3	321	912
November				2	308	1,032	7	316	915	1	330	871				1	323	1,010
December							2	298	922	1	333	865						
January				2	308	975	3	312	956							2	326	944
Average	34	326	932	6	306	1,013	15	315	929	2	332	868	3	341	925	8	334	927

Jasper:																		
September				4	314	950							2	343	960	3	341	865
October				1	268	985							2	331	1,051	2	344	864
November				5	311	1,010												
December				1	281	1,054	1	297	915	1	336	956				1	324	921
January				5	305	1,039												
Average	28	320	954	16	296	1,008	1	297	915	1	336	956	4	337	1,006	6	336	883
Kershaw:																		
September				7	296	982	3	322	950	3	346	890	12	335	975	7	344	912
October				1	313	1,045	2	336	922	3	353	884	22	337	956	9	339	921
November				7	314	1,016				1	374	865	1	361	1,054	9	343	925
December							3	320	947	3	330	944				11	330	893
January							1	331	1,013							7	337	915
Average	112	334	955	15	308	1,014	9	327	958	10	351	896	35	344	995	43	339	913
Lancaster:																		
September				2	294	922	1	312	906	1	341	858	4	345	966	1	343	912
October				1	314	982				1	347	909	12	337	944	8	338	884
November				1	312	997				1	344	868				14	344	884
December																4	350	906
Average	51	330	921	4	307	967	1	312	906	3	344	878	16	341	955	27	344	897
Laurens:																		
September				8	303	963	3	319	972	7	349	884	19	344	934	23	345	963
October				10	315	979	8	316	940	6	344	887	45	341	931	40	333	922
November				13	329	953	5	336	928	4	347	871	4	330	947	33	339	931
December				2	318	982				4	329	899				17	339	941
January				16	325	918				4	338	896	1	336	868	9	335	934
Average	231	332	930	49	318	959	16	324	947	25	341	887	69	338	920	122	338	938
Lee:																		
September				8	305	960	5	319	906				9	334	947	11	331	925
October				3	314	944	12	309	918	4	322	893	22	333	956	21	333	912
November				2	273	985	15	318	953	7	325	896	2	344	969	11	334	934
December				2	317	1,013	10	315	931	1	310	906				15	333	906
January				2	312	975	8	314	953	4	325	921	1	314	991	1	330	893
Average	176	321	938	17	304	975	50	315	932	16	321	904	34	331	966	59	332	914
Lexington:																		
September				15	292	985	4	329	972	5	330	899	13	342	944	9	340	893
October				21	294	1,058	16	314	958	3	334	880	18	340	931	19	334	903
November				13	305	1,004	5	323	956				3	334	972	13	330	921
December				2	306	988	3	321	953				3	333	979	2	347	922
January				1	311	1,055	1	352	991							7	340	937
Average	176	327	949	52	302	1,018	29	328	966	8	332	890	37	337	957	50	338	915

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

SOUTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
McCormick:																		
September										3	351	852	22	338	963	9	343	940
October							2	319	959	17	336	874	36	335	959	13	325	940
November										17	333	903	8	318	1,001	27	329	940
December							2	344	966	7	326	912				12	320	956
January										3	330	893	1	332	966	2	314	941
Average	181	331	941				4	332	963	47	335	887	67	331	972	63	326	943
Marion:																		
September				6	292	994	5	324	893	1	329	890	5	352	950	5	352	1,004
October				4	283	1,016	6	313	890	1	334	921	20	342	960	8	336	1,001
November				5	292	991	6	324	956							7	344	1,020
December				6	293	991	2	314	922				1	344	978	8	333	1,017
January				3	303	985	4	318	940							3	336	1,013
Average	106	326	959	24	293	995	23	319	920	2	332	906	26	346	963	31	340	1,011
Marlboro:																		
September				35	298	1,020	15	328	912	14	335	883	96	344	975	41	343	959
October				3	295	1,010	26	325	944	4	358	915	77	349	978	92	340	963
November				10	306	997	23	331	940	2	341	975	5	349	994	63	335	953
December				11	310	1,001	9	328	966	3	314	928	3	340	1,001	23	337	963
January				6	307	1,017	6	330	979	1	328	922				19	333	953
Average	587	330	965	65	303	1,009	79	328	948	24	335	925	181	346	987	238	338	958
Newberry:																		
September				8	301	966	5	329	997	1	321	855	14	338	941	14	340	940
October				5	320	950	2	338	915				9	341	931	36	327	925
November				9	320	950	3	346	925	1	321	877	1	342	963	33	341	925
December				6	298	969				2	318	934				28	335	903
January				8	310	937										8	330	890
Average	193	329	930	36	310	954	10	338	946	4	320	889	24	340	945	119	335	917

Oconee:																		
September				1	305	950	1	359	963	1	335	928						
October													1	346	1,001	1	315	937
November										1	346	928						
January										1	324	883						
Average	7	332	953	1	305	950	1	359	963	3	335	913	1	346	1,001	1	315	937
Orangeburg:																		
September				40	293	969	26	322	912	12	343	909	26	335	956	27	356	877
October				17	299	994	42	318	931	6	335	909	46	335	966	38	348	887
November				25	293	969	27	302	956	6	329	1,004				29	347	912
December				13	288	972	25	300	959	11	323	928				16	340	928
January				18	292	988	15	316	960	1	325	972	1	359	1,064	24	350	909
Average	491	325	953	113	293	978	135	312	944	36	331	944	73	343	995	134	348	903
Pickens:																		
September										1	334	823						
October				1	350	918							1	336	931			
November							3	347	909									
January				12	319	909				2	324	858						
Average	20	337	899	13	335	914	3	347	909	3	329	841	1	336	931			
Richland:																		
September				26	303	956	13	330	953	19	336	925	34	341	1,013	21	353	874
October				9	318	1,001	13	315	944	6	349	950	16	344	982	21	342	893
November				14	311	960	11	327	975	4	342	959				28	338	899
December				2	305	1,029	6	323	953	7	331	940	1	331	874	4	333	890
January				1	283	921	1	321	966	1	302	877				6	339	915
Average	264	328	942	52	304	973	44	323	958	37	332	930	51	339	956	80	341	894
Saluda:																		
September				3	288	1,029	1	325	982				5	344	931	7	341	966
October				2	297	1,042	6	318	950	2	348	944	3	318	925	3	351	925
November				1	289	1,054	2	312	966				2	314	1,023	15	326	978
December				2	303	1,026	1	285	960	2	326	931				3	326	941
January				2	306	1,026												
Average	62	321	970	10	297	1,035	10	310	965	4	337	938	10	325	960	28	336	953
Spartanburg:																		
September				5	305	928				2	342	931	2	374	909	5	350	918
October				4	322	931	2	307	884	4	344	937	16	342	931	14	330	959
November				2	306	912	4	324	931	7	343	868				7	337	947
December				1	341	1,016	1	319	937	8	335	880				3	333	937
January				4	315	947				2	342	899	1	304	934	10	333	953
Average	104	331	927	16	318	947	7	317	917	23	341	903	19	340	925	39	337	943

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

SOUTH CAROLINA—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds*		*Pounds.*	*Pounds.*
Sumpter:																		
September				28	305	991	38	324	928	14	338	915	39	337	988	34	331	883
October				9	319	1,001	36	318	941	29	340	915	39	334	956	60	310	915
November				8	323	985	25	315	966	28	333	925				29	337	925
December				2	340	985	20	307	953	22	321	944				19	331	918
January				9	308	994	15	314	953	11	323	921				22	327	921
Average	536	327	949	56	319	991	134	316	948	104	331	924	78	336	972	164	333	912
Union:																		
September				8	318	937	2	325	903	3	352	906	4	353	963	9	349	940
October				7	315	940	13	328	890	6	345	912	21	346	934	10	338	947
November				7	315	890	9	327	912	7	345	884	1	327	883	3	347	915
December				2	315	978	7	309	884							2	320	887
January				1	329	937	1	343	918							1	316	902
Average	124	333	917	25	318	936	32	326	901	16	347	901	26	342	927	25	334	918
Williamsburg:																		
September				4	280	950	8	308	902	2	326	899	30	315	937	20	355	877
October				15	297	937	33	295	883				43	318	940	45	346	890
November				12	306	947	20	293	928							14	334	909
December				7	298	978	20	294	922	5	295	868				6	339	931
January				17	287	960	13	290	921							16	328	903
Average	330	311	918	55	294	954	94	296	911	7	310	884	73	317	939	101	340	903
York:																		
September				7	313	966				4	345	950	21	351	969	11	351	918
October				2	340	1,036	7	334	883	3	340	884	44	353	934	29	332	931
November				6	319	982	12	332	893	7	347	890				13	339	931
December				3	314	944	1	297	811	8	334	871	1	333	934	3	337	940
January				4	312	922	1	297	871	4	317	893				11	325	909
Average	202	331	921	22	320	970	21	315	865	26	337	898	66	346	946	67	337	926

TENNESSEE.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	1,323	308	985	623	294	1,040	255	318	916	192	319	957	185	312	987	68	291	1,025
Bedford	6	321	1,015	4	307	1,073	1	336	966	1	319	1,007						
Benton	10	298	975	4	278	1,052	4	304	866				2	311	1,007			
Bledsoe	1	321	883				1	321	883									
Bradley	1	302	925							1	302	925						
Carroll	59	316	971	35	282	1,018	18	317	886	1	346	994	5	319	987			
Carter	1	312	1,032	1	312	1,032												
Chester	9	309	977	6	278	1,016	3	339	937									
Coffee	1	269	1,070	1	269	1,070												
Crockett	53	290	971	11	280	1,014	9	290	891	20	306	980	12	299	1,000	1	275	
Davidson	27	308	974							1	335	940	12	295	961	14	294	1,015
Decatur	4	322	1,075	3	293	1,082							1	350	1,067			
Dickson	1	336	966													1	336	966
Dyer	85	301	1,004	8	294	1,035	14	324	919	41	312	951	21	302	979	1	271	1,134
Fayette	72	304	993	60	288	1,029	5	304	1,000	3	322	921	2	298	959	2	310	1,058
Franklin	1	320	937							1	320	937						
Gibson	89	298	984	19	290	1,067	35	327	889	7	312	991	16	287	977	12	274	997
Giles	98	319	993	86	297	1,054							10	341	950	2	320	974
Hamilton	1	308	1,121	1	308	1,121												
Hardeman	59	314	965	35	294	1,041	18	322	899	4	327	896	2	314	1,023			
Hardin	35	295	1,027	1	285	1,067							34	305	987			
Hankins	1	241														1	241	
Haywood	39	301	998	26	292	1,031	6	310	887	5	304	1,006				2	298	1,070
Henderson	20	298	964	15	301	1,024	1	276	890	1	288	959	3	327	982			
Knox	1	326	975										1	326	975			
Henry	16	306	936	12	296	1,010	4	315	861									
Houston	1	338	997				1	338	997									
Jefferson	1	329	963				1	329	963									
Lake	29	309	976	11	313	1,006	11	315	922				7	301	1,001			
Lauderdale	111	304	975	23	285	1,028	19	325	909	45	314	969	22	301	988	2	293	979
Lawrence	16	329	951	12	311	1,005	2	336	910	2	340	937						

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TENNESSEE—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Lincoln	6	301	1,066	6	301	1,066												
McMinn	4	301	938	2	298	985	1	291	874	1	315	956						
McNairy	10	317	983	8	298	1,039	2	335	926									
Madison	66	301	976	24	286	1,017	8	320	931	5	309	962	15	297	978	14	291	994
Maury	2	312	1,041	2	312	1,041												
Monroe	1	319	883				1	319	883									
Obion	31	313	1,010	7	280	1,060	10	338	1,010	9	323	955	5	310	1,014			
Overton	2	306	1,055	2	306	1,055												
Polk	13	318	954	2	314	993	4	306	925	7	333	944						
Rutherford	40	322	1,023	25	309	1,043				4	334	948	9	325	1,028	2	319	1,073
Shelby	183	306	972	126	284	1,008	33	309	878	13	309	974	3	323	971	8	304	1,028
Stewart	1	336								1	336							
Sumner	3	321	920							3	321	920						
Tipton	81	304	975	31	290	1,010	29	319	897	14	315	930	2	317	1,023	5	278	1,013
Washington	1	283	1,137	1	283	1,137												
Weakly	29	305	965	12	277	1,022	15	324	877	2	314	1,004						
White	1	268														1	268	
Wayne	1	303	978										1	303	978			

By Counties and Months.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Bedford:																		
September				1	300	1,067												
October				1	296	1,045	1	336	966									
November				1	321	1,118				1	319	1,007						
December				1	311	1,061												
Average	6	321	1,015	4	307	1,073	1	336	966	1	319	1,007						
Benton:																		
October				3	267	1,048												
November				1	289	1,055	3	303	864				2	311	1,007			
December							1	304	868									
Average	10	298	975	4	278	1,052	4	304	866				2	311	1,007			
Bledsoe:																		
September							1	321	883									
Average	1	321	883				1	321	883									
Bradley:																		
December										1	302	925						
Average	1	302	925							1	302	925						
Carroll:																		
September				7	260	1,042												
October				7	278	1,055	2	316	925	1	346	994	2	334	1,013			
November				4	296	1,023	16	318	846				3	304	960			
December				7	292	1,013												
January				10	286	979												
Average	59	316	971	35	282	1,018	18	317	886	1	346	994	5	319	987			
Carter:																		
January				1	312	1,032												
Average	1	312	1,032	1	312	1,032												

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TENNESSEE—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Chester:																		
September				3	256	969												
October				1	274	1,035												
November				1	300	1,051	3	339	937									
December				1	282	1,007												
Average	9	309	977	6	278	1,016	3	339	937									
Crockett:																		
September				2	261	1,051	1	265	883	2	329	985						
October				3	297	1,035	4	300	921	5	316	1,016	2	295	1,010	1	275	
November				1	297	1,035	4	306	868	8	301	997	6	304	982			
December				3	285	960				4	290	931	4	298	1,007			
January				2	262	991				1	296	969						
Average	53	290	971	11	280	1,014	9	290	891	20	306	980	12	299	1,000	1	275	
Coffee:																		
December				1	269	1,070												
Average	1	269	1,070	1	269	1,070												
Davidson:																		
October													3	320	966	3	300	1,026
November													5	296	969	3	301	1,016
December										1	335	940	3	292	966	5	292	1,013
January													1	271	941	3	282	1,004
Average	27	308	974							1	335	940	12	295	961	14	294	1,015
Decatur:																		
November				2	280	1,080							1	350	1,067			
December				1	305	1,083												
Average	4	322	1,075	3	293	1,082							1	350	1,067			

Dickson:																		
November																1	336	966
Average	1	336	966													1	336	966
Dyer:																		
September				3	272	1,054				1	325	966						
October				2	281	1,054	5	325	956	11	331	966	4	304	982			
November				2	328	1,042	6	333	934	14	321	934	9	313	978			
December				1	296	991				12	303	912	8	288	978			
January							3	314	868	3	282	975				1	271	1,134
Average	85	301	1,004	8	294	1,035	14	324	919	41	312	951	21	302	979	1	271	1,134
Fayette:																		
September				12	278	1,051	1	267	1,112							2	310	1,058
October				12	295	1,039				1	338		2	298	959			
November				11	294	1,035	3	317	887									
December				7	285	1,007	1	328		2	305	921						
January				18	288	1,013												
Average	72	304	993	60	288	1,029	5	304	1,000	3	322	921	2	298	959	2	310	1,058
Franklin:																		
January										1	320	937						
Average	1	320	937							1	320	937						
Gibson:																		
September				8	269	1,055				4	302	1,026						
October				1	308	1,187	7	326	928	2	339	1,016	5	290	991	3	273	985
November				3	296	1,118	26	328	874				8	292	978	4	276	1,010
December				6	286	1,001	2	326	865	1	296	931	3	280	963	5	274	997
January				1	289	972												
Average	89	298	984	19	290	1,067	35	327	889	7	312	991	16	287	977	12	274	997
Giles:																		
September				3	287	1,089												
October				12	295	1,067							10	341	950	1	299	988
November				30	298	1,051										1	340	960
December				21	303	1,026												
January				20	301	1,039												
Average	98	319	993	86	297	1,054							10	341	950	2	320	974
Hamilton:																		
October				1	308	1,121												
Average	1	308	1,121	1	308	1,121												

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TENNESSEE—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Hardeman:																		
September				8	276	1,073	3	309	956	4	327	896						
October				2	303	1,061	2	321	849									
November				8	314	1,020	10	316	899				2	314	1,023			
December				8	292	1,017	3	341	893									
January				9	283	1,036												
Average	59	314	965	35	294	1,041	18	322	899	4	327	896	2	314	1,023			
Hardin:																		
September				1	285	1,067												
October													7	306	1,023			
November													18	307	966			
December													7	296	975			
January													2	311	985			
Average	35	295	1,027	1	285	1,067							34	305	987			
Hawkins:																		
September																1	241	
Average	1	241														1	241	
Haywood:																		
September				10	272	1,036	2	317	940	4	312	1,013				2	298	1,070
October				6	294	1,073												
November				3	309	1,020	3	318	868									
December				3	300	1,016	1	294	852	1	295	998						
January				4	287	1,010												
Average	39	301	998	26	292	1,031	6	310	887	5	304	1,006				2	298	1,070

Henderson:																		
September				1	327	1,061				1	288	959						
October				5	284	1,007							1	337	969			
November				4	310	1,051	1	276	890				2	317	994			
December				2	295	1,016												
January				3	288	985												
Average	20	298	964	15	301	1,024	1	276	890	1	288	959	3	327	982			
Henry:																		
September				1	277	994												
October				5	277	1,025												
November				2	313	997	4	315	861									
December				1	316	1,035												
January				3	296	998												
Average	16	306	936	12	296	1,010	4	315	861									
Houston:																		
October				1	338	997												
Average	1	338	997	1	338	997												
Jefferson:																		
November							1	329	963									
Average	1	329	963				1	329	963									
Knox:																		
November													1	326	975			
Average	1	326	975										1	326	975			
Lake:																		
September				3	301	998	1	320	1,051									
October				5	300	994												
November				2	331	1,051	9	339	868				3	302	988			
December				1	319	982	1	285	846				4	299	1,013			
Average	29	309	976	11	313	1,006	11	315	922				7	301	1,001			
Lauderdale:																		
September				6	272	1,032	1	335	846	7	304	966				1	324	979
October				13	286	1,010	2	323	902	6	313	975	1	309				
November				3	289	1,042	11	328	864	12	312	953	12	303	997			
December							3	329	871	19	304	934	9	290	978	1	262	
January				1	294	1,029	2	310	1,064	1	336	1,017						
Average	111	304	975	23	285	1,028	19	325	909	45	314	969	22	301	988	2	293	979

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TENNESSEE—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Lawrence:																		
October				1	332	1,064												
November				5	310	1,051	1	350	937	2	340	937						
December				3	306	940												
January				3	295	963	1	322	883									
Average	16	329	951	12	311	1,005	2	336	910	2	340	937						
Lincoln:																		
October				4	299	1,032												
December				1	312	1,026												
January				1	293	1,140												
Average	6	301	1,066	6	301	1,066												
McMinn:																		
September				1	288	1,064												
November				1	308	906												
December							1	291	874	1	315	956						
Average	4	301	938	2	298	985	1	291	874	1	315	956						
McNairy:																		
September				3	283	1,096	1	351	921									
October				1	299	1,020												
November				2	312	1,067	1	318	931									
December				1	299	1,013												
January				1	298	998												
Average	10	317	983	8	298	1,039	2	335	926									

Madison:																		
September				10	265	1,051				1	331	963						
October				5	280	1,017	2	310	959				4	306	994	1	286	1,020
November				4	314	1,077	6	330	903				6	298	997	5	295	982
December				2	288	937				3	282	956	3	295	978	5	289	988
January				3	281	1,004				1	314	966	2	289	941	3	292	985
Average	66	301	976	24	286	1,017	8	320	931	5	309	962	15	297	978	14	291	994
Maury:																		
December				1	311	1,045												
January				2	312	1,036												
Average	2	312	1,041	2	312	1,041												
Monroe:																		
December							1	319	883									
Average	1	319	883				1	319	883									
Obion:																		
September				2	270	1,096	1	326	1,083									
October				1	276	1,092				3	330	997						
November							9	349	937	3	332	960	1	333	1,045			
December				3	284	1,039				3	307	909	4	287	982			
January				1	288	1,013												
Average	31	313	1,010	7	280	1,060	10	338	1,010	9	323	955	5	310	1,014			
Overton:																		
October				2	306	1,055												
Average	2	306	1,055	2	306	1,055												
Polk:																		
November				1	308	979	2	315	903	2	331	944						
December				1	319	1,007	1	308	1,010	3	329	928						
January							1	296	861	2	339	959						
Average	13	318	954	2	314	993	4	306	925	7	333	944						
Rutherford:																		
September				1	310	1,058												
October				7	310	1,054				3	353	940	5	320	1,026			
November													4	330	1,029	1	331	1,0[illegible]
December				6	313	1,054												
January				11	302	1,004				1	315	956				1	307	1,054
Average	40	322	1,023	25	309	1,043				4	334	948	9	325	1,028	2	319	1,073

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TENNESSEE—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Shelby:																		
September				26	267	1,039	4	302	896	3	299	1,035	1	334	937	5	339	1,001
October				22	281	1,032	2	334	899	1	326					2	303	1,054
November				12	300	1,001	17	306	880	4	301	931	2	312	1,004			
December				12	286	985	8	308	871	4	293	921				1	270	
January				54	285	982	2	296	846	1	325	1,007						
Average	183	306	972	126	284	1,008	33	309	878	13	309	974	3	323	971	8	304	1,028
Stewart:																		
December										1	336							
Average	1	336								1	336							
Sumner:																		
November										2	335	985						
December										1	307	855						
Average	3	321	920							3	321	920						
Tipton:																		
September				9	263	1,023	2	327	937	4	333	925						
October				15	290	1,017	10	320	921	1	323							
November				2	302	1,016	15	322	868	4	320	960	2	317	1,023	1	276	1,029
December				3	300	988	1	302	865	4	314	921				4	279	997
January				2	295	1,007	1	323	896	1	286	912						
Average	81	304	975	31	290	1,010	29	319	897	14	315	930	2	317	1,023	5	278	1,013
Washington:																		
October							1	283	1,137									
Average	1	283	1,137				1	283	1,137									

Weakley:																		
September										1	303	1,020						
October				5	277	1,080				1	325	988						
November				4	287	1,102	15	324	877									
December				1	260	982												
January				2	283	922												
Average	29	305	968	12	277	1,022	15	324	877	2	314	1,004						
White:																		
November																1	268	
Average	1	268														1	268	
Wayne:																		
November													1	303	978			
Average	1	303	978										1	303	978			

TEXAS.

By Counties.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	1,984	279	982	456	273	983	482	277	996	481	289	991	335	282	969	230	273	936
Anderson	25	266	958	3	293		5	289		8	293		3	280	958	6	275	
Angelina	3	254	955	2	245	979							1	262	931			
Archer	2	265	1,057	1	262	1,057												
Austin	12	284	1,023	1	281		4	275	1,012	4	302	1,034				1	267	
Bastrop	6	263	1,010				1	257		2	276		3	255	1,010	3	276	
Baylor	11	278	998				1	257	974	1	281	1,021	5	304	999	4	270	
Bee	1	285	863				1	285	863									
Bell	2	295	1,062				1	279	1,062	1	311							
Bexar	1	287	1,015	1	287	1,015												
Bosque	12	275	1,023	4	264		4	285	1,022	1	298	1,002	2	280	1,045	1	246	

TABLE VI.— *Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Bowie	17	296	909	8	298	935				7	290	980	2	299	812			
Brazoria	2	290		1	290		1	289										
Brazos	6	267	1,009	4	251	1,015							2	282	1,002			
Brown	4	272	972	3	265	1,010							1	279	934			
Burleson	6	271	1,023	1	275	1,062	2	278	1,017				3	260	991			
Burnet	2	269	940							1	273	931	1	265	948			
Caldwell	1	276	939										1	276	939			
Calhoun	2	255					1	272		1	238							
Callahan	4	266	1,006	1	244	955	1	238	1,057	1	311		1	271				
Cameron	1	276		1	276													
Camp	3	284	1,056				1	288	1,116	2	279	996						
Cherokee	7	289	981	2	298	1,021				4	274	940				1	295	
Childress	31	277	1,009	10	280	985	8	277	1,049	6	287	993	6	281	1,010	1	261	
Clay	2	266	1,045				2	266	1,045									
Coleman	3	289	965	1	298	912				2	279	1,018						
Collin	54	269	964	12	297	955	20	257	958	15	272	977	6	263	965	1	258	
Collingsworth	14	301	1,014	6	281	1,051	4	300	1,018	1	311	998	3	311	987			
Colorado	2	272	983										2	272	983			
Comal	5	282	1,020	2	285	988	1	275	1,083				2	285	990			
Comanche	4	273	991	3	280					1	266	991						
Concho	2	288					1	281		1	295							
Cooke	12	276	1,013				3	272	1,024	9	280	1,001						
Coryell	30	283	1,086	4	265		5	275	1,086	13	301		1	306		7	269	
Cottle	31	299	1,031	11	278	966	6	315	1,101	12	298	1,037	2	305	1,018			
Crosby	27	306	981	8	299	1,005	4	298	956	9	320	952	4	302	1,009	2	311	
Dallas	28	272	956	15	263	928	6	259	975	1	296		4	260	964	2	282	
Dawson	7	297	1,012	3	281	968				4	312	1,056						
Delta	17	292	963	3	277	1,007	1	278	991	7	313	973	6	298	881			
Denton	16	273	1,015	3	260	1,050	6	265	996	6	283	1,034	1	284	979			
De Witt	12	268	966	5	257	986							7	278	945			

Dickens	6	275	1,022	2	267	1,088	1	257	1,059	2	293	996	1	284	945			
Donley	5	321	1,016				3	304	1,025	1	337	955	1	322	1,069			
Duval	2	243	981							1	262	1,038	1	224	924			
Eastland	8	299	931	2	276		3	292	943	2	314	950	1	315	901			
Ellis	49	259	991	7	261	998	12	244	1,000	23	283	983	7	249	981			
El Paso	2	296	903	1	342	903	1	250										
Erath	9	275	1,006	2	263		2	269	1,081				1	299	931	4	270	
Falls	43	267	1,005	3	259	969	2	263		15	283	1,042	18	272	1,006	5	258	
Fannin	44	281	954	2	274	964	26	288	1,022	2	284	909	7	286	921	7	271	
Fayette	8	286	831				1	274		2	290		1	290	831	4	289	
Fisher	13	283	1,044	2	266	1,069	2	267	1,081	6	280	1,023	2	309	1,002	1	289	
Floyd	25	309	985	5	301	931				17	325	963	2	315	1,060	1	296	
Foard	15	298	1,048				2	306	1,119	7	294	1,004	3	298	1,020	3	284	
Fort Bend	35	278	951	8	284	877	7	276	1,002	9	297		5	262	974	6	271	
Franklin	2	275					1	279								1	271	
Freestone	8	264	955				2	257	939				6	270	971			
Frio	2	243	1,021	1	243	960	1	243	1,081									
Gaines	1	280														1	280	
Garza	4	303	923							3	295	924	1	311	922			
Goliad	3	271	999				1	276	1,015				2	265	983			
Gonzales	9	283	1,019							2	291	1,055	6	281	983	1	277	
Grayson	29	282	967	2	288	1,034	16	273	986	6	285	971	1	279	998	4	285	844
Gregg	5	274	862	3	265	886	1	270	758	1	287	962						
Grimes	11	285	977				2	291	991	3	296		2	272	962	4	280	
Guadalupe	27	273	958	3	269	991	8	250	952				3	293	921	13	280	967
Hale	4	268	875	2	280	875	1	272								1	253	
Hall	76	293	1,012	8	296	1,038	28	286	1,036	23	313	1,004	16	286	968	1	282	
Hamilton	7	380	967	3	256		3	248	967							1	256	
Hardeman	26	295	1,011	3	269	997	5	296	1,075	11	298	1,027	5	310	1,025	2	302	929
Hardin	1	288	962										1	288	962			
Harris	5	277	1,064							2	290		3	263	1,064			
Harrison	19	285	935	4	297	909	3	286	987	9	274	953	3	281	891			
Haskill	13	259	985	3	249	1,020	4	241	944	6	287	991						
Henderson	22	275	952	17	283	933	4	273	970							1	269	
Hidalgo	1	251											1	251				
Hill	41	274	973	4	278	977	12	267	942	13	292	986	6	279	986	6	256	
Hopkins	38	271	958	2	257	980	23	278	994	2	263	931	8	266	928	3	292	
Houston	41	278	929	1	267		7	279	945	12	395	882	5	273	959	16	275	
Howard	1	302	1,010										1	302	1,010			
Hunt	85	267	979	15	255	977	29	262	942	11	290	991	13	259	1,004	17	271	
Jack	3	242	1,062	3	242	1,062												
Jackson	4	296	958				3	288	958	1	313							
Jasper	4	249	992	4	249	992												
Jefferson	1	313	877										1	313	877			
Jim Wells	2	288	1,018	1	326	1,002							1	249	1,034			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Johnson	6	269	963				3	266	901	2	296	1,024				1	244	
Jones	39	275	1,013	2	294	1,032	5	257	1,036	23	295	1,041	9	254	942			
Kaufman	32	268	1,021	10	270	999	16	264	996	4	279	1,055	2	260	1,034			
Kendall	1	265	1,002				1	265	1,002									
Kent	2	266	1,030	1	255	1,069							1	276	991			
Knox	3	271	1,024	1	237	1,093				1	316	955				1	260	
Lamar	26	268	951				8	284	942	3	277	984	8	292	883	7	219	983
Lampasas	1	256	962										1	256	962			
Lavaca	6	277	915				1	252	901	2	280	882	3	294	961			
Lee	1	273	1,017				1	273	1,017									
Leon	11	273	965	2	254	1,000	1	253	977	2	287	993	1	308	891	5	254	
Liberty	4	268	982	2	282	949							1	240	1,015	1	281	
Limestone	15	273	990	4	259	962	2	273	1,018	4	288	994	3	271	985	2	276	
Live Oak	2	291	942				1	275	1,005	1	306	879						
Lubbock	18	303	999	11	296	976				5	325	980	2	287	1,041			
Lynn	9	285	985	3	286	980				4	295	994	2	273	981			
McCulloch	1	257														1	257	
McLennan	73	273	970	10	277	933	21	267	1,002	12	291	1,012	6	271	936	24	258	965
Madison	9	280	939				3	290	939	3	287					3	264	
Marion	13	284	908				3	292	926	8	267	925	2	293	874			
Mason	1	293	979				1	293	979									
Matagorda	5	280	939	2	276	939	1	288		2	277							
Maverick	6	295								6	295							
Medina	1	301	979				1	301	979									
Milam	27	269	1,000	16	265	956	5	257	1,033	3	269	1,026	3	284	984			
Mills	1	271		1	271													
Mitchell	4	279	1,018							1	288		2	296	1,018	1	252	
Montague	2	287					2	287										
Montgomery	6	265	976	3	267	985				1	257		2	270	967			
Morris	6	291	888				2	313	818	1	277	1,015	3	283	830			

Motley	27	294	1,008	14	283	974	4	278	1,018	5	302	1,001	4	313	1,038			
Nacogdoches	8	279	963	4	274	952				1	295		3	268	974			
Navarro	37	266	997	8	273	993	13	261	990	5	291	1,037	7	255	966	4	250	
Nolan	6	292	966							3	304	996	3	279	936			
Nueces	10	256	996	2	248	977							2	262	1,015	6	258	
Palo Pinto	1	284	1,093				1	284	1,093									
Panola	4	291	910	1	282								3	299	910			
Parker	6	270	1,006	3	240	1,000	1	288	1,026							2	282	991
Polk	14	293	976	3	291	1,038	3	284	909	3	321		5	275	981			
Pecos	1	282		1	282													
Rains	6	270	978	5	264	977	1	276	979									
Red River	17	288	931	4	295	1,000	9	315	911	2	267	950	2	276	863			
Refugio	8	274	1,024	2	262	967							3	289	1,081	3	270	
Robertson	14	278	984	7	264	961	2	277	1,055				1	274	1,012	4	298	929
Rockwall	13	259	951	2	251	969	9	260	950	1		934	1	267				
Runnels	13	283	971	2	302	958				3	283	960	3	273	996	5	275	
Rusk	16	278	937	11	277	932							4	279	941	1	279	
Sabine	3	262	936	3	262	936												
San Augustine	11	284	949	10	282	926							1	285	972			
San Jacinto	6	307	1,017	1	306		1	307	1,019	3	318		1	296	1,015			
San Patricio	2	251	993	2	251	993												
San Saba	2	286	1,105	1	290		1	282	1,105									
Schleicher	5	290	998	5	290	998												
Scurry	2	288	939							2	288	939						
Shelby	15	277	953	5	277	968	4	262	926	1	272	962	5	295	956			
Smith	9	277	947	4	292		2	258	962				3	281	932			
Somervell	1	280		1	280													
Stephens	2	291	1,072				1	308	1,129	1	273	1,015						
Stonewall	3	287	952	1	247	1,040				1	301	991	1	314	825			
Tarrant	27	276	998	5	267		7	269	948	7	295	1,055	2	274	992	6	273	
Taylor	7	275	1,055	1	252	1,124				3	287	1,057	3	285	984			
Terry	7	282	911	7	282	911												
Titus	5	304	1,011				3	312	1,010	2	295	1,011						
Tom Green	1	281														1	281	
Travis	16	281	977	5	257	967	4	271	949	1	314		4	283	1,015	2	282	
Trinity	4	265	961	3	257	961				1	273							
Tyler	1	258	886	1	258	886												
Upshur	6	277	953	1	273	926	3	287	913	2	272	1,021						
Upton	1	254	1,050							1	254	1,050						
Van Zandt	4	271	1,001	1	269	1,017	2	267	1,006	1	276	979						
Victoria	6	270	947	2	251	947				2	265		1	294		1	269	
Walker	14	284	1,001	8	276	1,001	1	290		3	298					2	272	
Waller	12	280	960				3	276		4	295		1	277	960	4	270	
Ward	3	294	941				2	295	941							1	292	
Washington	2	288	973				1	275	977				1	301	969			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES—Continued.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Webb	2	286	1,028				1	314	1,045	1	257	1,010						
Wharton	7	285	947				2	278	1,017	3	281					2	297	877
Wheeler	5	306	993				5	306	993									
Wichita	6	281	1,052	1	241	1,045	2	292	1,073	2	281	1,056	1	308	1,034			
Wilbarger	9	279	1,023	2	265	1,030	3	275	1,045	1	298	1,038	2	289	980	1	267	
Williamson	17	277	1,002				1	302	950	9	259	1,041	7	269	1,016			
Wilson	1	281	1,053										1	281	1,053			
Wise	18	277	1,003	8	264	983	3	282	998	3	295	1,028				4	266	
Wood	10	288	918	2	287	896	2	261	955	3	283	972	2	308	848	1	299	
Young	13	278	1,032	7	256	1,040	3	292	1,070	1	265	979	1	310	1,040	1	266	

BY COUNTIES AND MONTHS.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Anderson:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
September				1	290		1	280		1	294					1	277	
October							1	289		4	299		3	280	958	2	285	
November							2	281								1	278	
December							1	304		3	286							
January				2	295											2	260	
Average	25	266	958	3	293		5	289		8	293		3	280	958	6	275	

Angelina:																		
September				2	245	979												
October													1	262	931			
Average	3	254	955	2	245	979							1	262	931			
Archer:																		
September				1	262	1,057												
December																1	267	
Average	2	265	1,057	1	262	1,057										1	267	
Austin:																		
September							2	282	1,012	2	287					1	275	
October				1	281					1	296	1,034				2	277	
November							1	268										
December							1	275		1	323							
Average	12	284	1,023	1	281		4	275	1,012	4	302	1,034				3	276	
Bastrop:																		
October										1	278		2	284	1,010			
December							1	257		1	274		1	225				
Average	6	263	1,010				1	257		2	276		3	255	1,010			
Baylor:																		
September										1	281	1,021	1	313	1,069			
November																3	276	
December																1	264	
January							1	257	974				4	294	929			
Average	11	278	998				1	257	974	1	281	1,021	5	304	999	4	270	
Bee:																		
September							1	285	863									
Average	1	285	863				1	285	863									
Bell:																		
November							1	279	1,062									
December										1	311							
Average	2	295	1,062				1	279	1,062	1	311							
Bexar:																		
November				1	287	1,015												
Average	1	287	1,015	1	287	1,015												

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Bosque:																		
September				2	258		3	246	986				1	292	1,045			
October				2	270					1	298	1,002						
November							1	324	1,057				1	267		1	246	
Average	12	275	1,023	4	264		4	285	1,022	1	298	1,002	2	280	1,045	1	246	
Bowie:																		
September										3	326	941	2	299	812			
October				1	302	1,005				1	275	986						
November										1	282							
December				5	295	891				2	276	1,012						
January				2	297	910												
Average	17	296	909	8	298	935				7	290	980	2	299	812			
Brazoria:																		
October				1	290													
December							1	289										
Average	2	290		1	290		1	289										
Brazos:																		
September				1	238	998												
October				1	259	993							2	282	1,002			
November				1	252	1,045												
December				1	256	1,024												
Average	6	267	1,009	4	251	1,015							2	282	1,002			
Brown:																		
October				2	264	1,010							1	279	934			
December				1	266													
Average	4	272	972	3	265	1,010							1	279	934			

Burleson:																		
September							2	278	1,017									
October				1	275	1,062							3	260	991			
Average	6	271	1,023	1	275	1,062	2	278	1,017				3	260	991			
Burnet:																		
October													1	265	948			
December										1	273	931						
Average	2	269	940							1	273	931	1	265	948			
Caldwell:																		
November													1	276	939			
Average	1	276	939										1	276	339			
Calhoun:																		
September							1	272		1	238							
Average	2	255					1	272		1	238							
Callahan:																		
September				1	244	955	1	238	1,057									
October										1	311							
December																1	271	
Average	4	266	1,006	1	244	955	1	238	1,057	1	311					1	271	
Cameron:																		
January				1	276													
Average	1	276		1	276													
Camp:																		
September							1	288	1,116	2	279	996						
Average	3	284	1,056				1	288	1,116	2	279	996						
Cherokee:																		
September										1	296	882						
October										2	248	922						
November				1	284	1,021										1	295	
December										1	278	1,017						
January			1	301														
Average	7	289	981	2	298	1,021				4	274	940				1	295	
Childress:																		
September				2	250	1,069	4	269	1,053	1	276	1,038						
October				1	249	1,026	3	318	1,107	1	314	974	3	291	1,036			
November				1	298	917	1	244	986	1	284	934				1	261	
December				5	292	983				3	273	1,026	1	287	1,010			
January				1	313	929							2	265	983			
Average	31	277	1,009	10	280	985	8	277	1,049	6	287	993	6	281	1,010	1	261	

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Clay:																		
September				2	266	1,045												
Average	2	266	1,045	2	266	1,045												
Coleman:																		
October				1	298	912												
November										1	278	991						
January										1	280	1,045						
Average	3	289	965	1	298	912				2	279	1,018						
Collin:																		
September				5	355	969	6	235	953	9	295	1,029	4	280	969			
October							3	271	960	2	294	1,002	1	258	996	1	258	
November				3	270	945	3	264	974									
December							8	256	943	3	222	891						
January				4	266	950				1	276	986	1	252	929			
Average	54	269	964	12	297	955	20	257	958	15	272	977	6	263	965	1	258	
Collingsworth:																		
October				1	276	1,131												
November				1	290	1,057	1	330	1,062				1	315	1,050			
December				2	298	1,026	3	270	974				1	339	1,043			
January				2	261	991				1	311	998	1	280	867			
Average	14	301	1,014	6	281	1,051	4	300	1,018	1	311	998	3	311	987			
Colorado:																		
September													1	280	983			
October													1	264	983			
Average	2	272	983										2	272	983			

Comal:																		
September							1	275	1,083									
October				1	299	969							1	272	974			
November													1	297	1,005			
December				1	271	1,007												
Average	5	282	1,020	2	285	988	1	275	1,083				2	285	990			
Comanche:																		
September										1	266	991						
October				1	268													
January				2	291													
Average	4	273	991	3	280					1	266	991						
Concho:																		
October							1	281										
November										1	295							
Average	2	288					1	281		1	295							
Cooke:																		
September							3	272	1,024	6	294	996						
December										3	265	1,005						
Average	12	276	1,013				3	272	1,024	9	280	1,001						
Coryell:																		
September				1	257					4	303		1	306		1	276	
October				1	262		2	279		4	297					2	266	
November							2	269		4	300					3	264	
December							1	278	1,086	1	304					1	270	
January				2	277													
Average	30	283	1,086	4	265		5	275	1,086	13	301		1	306		7	269	
Cottle:																		
September				2	256	1,015	1	306	1,121				1	329	1,021			
October				1	304	1,026	2	321	1,116	6	314	1,048						
November				1	287	1,015	3	317	1,067									
December				1	281					5	285	1,029						
January				6	263	810				1	294	1,034	1	280	1,015			
Average	31	299	1,031	11	278	966	6	315	1,101	12	298	1,037	2	305	1,018			
Crosby:																		
September				1	275	1,026				1	336	903						
October							2	315	1,021				2	298	1,038			
November				3	322	988				1	342	967				2	311	
December				3	294	960				6	317	958	1	292	1,021			
January				1	303	1,045	2	281	891	1	286	979	1	316	967			
Average	27	306	981	8	299	1,005	4	298	956	9	320	952	4	302	1,009	2	311	

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Dallas:																		
September				2	242	1,007	1	244	1,021	1	296		3	281	955	2	282	
October				1	259								1	239	972			
November				1	273	888	3	273	1,010									
December				3	266	865	1	280										
January				8	273	950	1	240	893									
Average	28	272	956	15	263	928	6	259	975	1	296		4	260	964	2	282	
Dawson:																		
September										1	320	1,021						
October				1	279	1,002				2	338	1,091						
November				1	294	943												
December										1	279	1,057						
January				1	270	958												
Average	7	297	1,012	3	281	968				4	312	1,056						
Delta:																		
September				3	277	1,007				5	309	981	3	297				
October										1	321	962	1	287	877			
December							1	278	991	1	308	977	2	310	884			
Average	17	292	963	3	277	1,007	1	278	991	7	313	973	6	298	881			
Denton:																		
September				2	258	1,050	1	274	1,010	6	283	1,034						
October							1	257	993				1	284	979			
November				1	261		3	281	1,088									
January							1	246	891									
Average	16	273	1,015	3	260	1,050	6	265	996	6	283	1,034	1	284	979			

De Witt:																		
September													2	282	945			
October													5	273	945			
November				3	274	969												
December				2	240	1,002												
Average	12	268	966	5	257	986							7	278	945			
Dickens:																		
September				2	267	1,088				1	303	1,036						
October							1	257	1,059									
November										1	282	955	1	284	945			
Average	6	275	1,022	2	267	1,088	1	257	1,059	2	293	996	1	284	945			
Donley:																		
September							1	331	962				1	322	1,069			
October							1	300	1,093									
November							1	280	1,021	1	337	955						
Average	5	321	1,016				3	304	1,025	1	337	955	1	322	1,069			
Duval:																		
October													1	224	924			
December										1	262	1,038						
Average	2	243	981							1	262	1,038	1	224	924			
Eastland:																		
September				2	276		1	252	1,021	2	314	950						
October							1	303	1,034				1	315	901			
November							1	322	774									
Average	8	299	931	2	276		3	292	943	2	314	950	1	315	901			
Ellis:																		
September				5	261	1,010	6	254	1,062	9	262	960	2	281	941			
October				2	260	986	1	232	1,005	1	299	907	1	249	962			
November							5	246	934	1	297	1,026	3	234	936			
December										12	275	1,038	1	230	1,086			
Average	49	259	991	7	261	998	12	244	1,000	23	283	983	7	249	981			
El Paso:																		
October							1	250										
November				1	342	903												
Average	2	296	903	1	342	903	1	250										

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Erath:																		
September				2	263		1	245	1,081									
October																1	275	
November													1	299	931	2	259	
December							1	292								1	276	
Average	9	275	1,006	2	263		2	269	1,081				1	299	931	4	270	
Falls:																		
September				2	247	969							8	276	981			
October							1	254		6	292		4	261	974			
November							1	272		4	280	1,040	2	279	1,024			
December										5	277	1,043	4	271	1,043	2	248	
January				1	271											3	267	
Average	43	267	1,005	3	259	969	2	263		15	283	1,042	18	272	1,006	5	258	
Fannin:																		
September				1	263		7	268	1,002				4	294	931			
October							1	306	1,093	1	301	941				3	263	
November							6	295	1,029				1	291	922	1	254	
December							3	299	1,017	1	267	877				2	263	
January				1	284	964	9	273	967				2	274	910	1	304	
Average	44	281	954	2	274	964	26	288	1,022	2	284	909	7	286	921	7	271	
Fayette:																		
September													1	290	831	3	278	
October																1	299	
December							1	274		2	290							
Average	8	286	831				1	274		2	290		1	290	831	4	289	

Fisher:																		
September				1	243	1,069	1	260	1,081	4	276	1,034	2	309	1,002	1	289	
October				1	289													
November							1	273	1,081									
December										2	284	1,012						
Average	13	282	1,044	2	266	1,069	2	267	1,081	6	280	1,023	2	309	1,002	1	289	
Floyd:																		
September				1	313	991				1	342	955						
October										4	352	983	1	321	1,055			
November				2	324	977				1	303	936	1	309	1,064	1	296	
December				2	265	825				11	304	977						
Average	25	309	985	5	301	931				17	325	963	2	315	1,060	1	296	
Foard:																		
September							1	291	1,116	1	293	974						
October							1	320	1,121	2	308	1,010	1	297	1,029			
November										1	295	1,029	1	284	1,081			
December										2	283	1,029	1	314	950	3	284	
January										1	292	979						
Average	15	298	1,048				2	306	1,119	7	294	1,004	3	298	1,020	3	284	
Fort Bend:																		
September				1	271		4	270	1,002	4	298		2	268	974	3	271	
October				4	291		1	280		2	300		2	267	931	2	261	
November				2	258	877	1	287					1	250	1,017			
December							1	266		3	293					1	280	
January				1	314													
Average	35	278	951	8	284	877	7	276	1,002	9	297		5	262	974	6	271	
Franklin:																		
October																1	271	
December							1	279										
Average	2	275					1	279								1	271	
Freestone:																		
September							1	265					5	270	948			
October							1	248	939				1	270	993			
Average	8	264	955				2	257	939				6	270	971			
Frio:																		
September				1	243	960												
October							1	243	1,081									
Average	2	243	1,021	1	243	960	1	243	1,081									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Gaines:																		
September																1	280	
Average	1	280														1	280	
Garza:																		
September													1	311	922			
November										2	324	945						
December										1	264	903						
Average	4	303	923							3	295	924	1	311	922			
Goliad:																		
September							1	276	1,015									
October													2	265	983			
Average	3	271	999				1	276	1,015				2	265	983			
Gonzales:																		
September													2	281	953	1	277	
October										2	291	1,055	4	281	1,012			
Average	9	982	1,019							2	291	1,055	6	281	983	1	277	
Grayson:																		
September				1	267	1,034	5	277	1,036	4	285	988	1	279	998	2	285	
October							2	267	986	1	286					1	258	
November				1	308		6	270	967	1	284	953						
December							3	277	953							1	312	844
Average	29	282	967	2	288	1,034	16	273	986	6	285	971	1	279	998	4	285	844

Gregg:																		
September							1	270	758									
December				3	265	886				1	287	962						
Average	5	274	862	3	265	886	1	270	758	1	287	962						
Grimes:																		
September							2	291	991							2	275	
October										2	304		2	272	962	1	287	
November																1	279	
December										1	288							
Average	11	285	977				2	291	991	3	296		3	272	962	4	280	
Guadalupe:																		
September				3	269	991	3	254	974				1	299	891	1	296	1,126
October							3	247	991				2	287	950	3	285	953
November							2	249	891							5	292	922
December																1	258	912
January																3	270	924
Average	27	273	928	3	269	991	8	250	952				3	293	921	13	280	967
Hale:																		
October				1	291	934										1	253	
December				1	268	815	1	272										
Average	4	268	875	2	280	875	1	272								1	253	
Hall:																		
September				1	294	1,057	8	314	1,067	2	314	1,072						
October				1	295	1,100	5	312	1,088	1	355	974				1	282	
November				5	301	1,005	11	291	1,026	13	296	981	4	290	1,034			
December				1	292	988	3	265	1,015	7	285	988	7	295	967			
January							1	247	986				5	272	903			
Average	76	293	1,012	8	296	1,038	28	286	1,036	23	313	1,004	16	286	968	1	282	
Hamilton:																		
September				2	250		2	240	1,005									
October				1	261													
December							1	255	929							1	256	
Average	7	380	967	3	256		3	248	967							1	256	
Hardeman:																		
September				1	233	998	2	279	1,110	5	304	1,038						
October							2	301	1,069				2	280	1,031			
November							1	309	1,045				1	299	1,043			
December				2	305	996				6	291	1,015	1	317	1,015	1	300	
January													1	343	1,010	1	304	929
Average	26	295	1,011	3	269	997	5	296	1,075	11	298	1,027	5	310	1,025	2	302	929

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Hardin:																		
October													1	288	962			
Average	1	288	962										1	288	962			
Harris:																		
September										1	266							
October										1	314		2	227	1,064			
December													1	299				
Average	5	277	1,064							2	290		3	263	1,064			
Harrison:																		
September				2	295	953	2	282	893	7	260	922	3	281	891			
October							1	289	1,081	1	278	936						
December				1	307	869				1	284	1,002						
January				1	288	905												
Average	19	285	935	4	297	909	3	286	987	9	274	953	3	281	891			
Haskill:																		
September				2	245	1,043	1	234	1,021	3	298	1,007						
October				1	253	996	1	234	974									
November							1		1,000									
December										3	276	974						
January							1	254	782									
Average	13	259	985	3	249	1,020	4	241	944	6	287	991						
Henderson:																		
September				10	275	941	3	262	991									
October				4	297	948	1	284	948									
November				3	277	910												
December																1	269	
Average	22	275	952	17	283	933	4	273	970							1	269	

Hidalgo:																		
September													1	251				
Average	1	251											1	251				
Hill:																		
September				1	240	977	4	278	962	2	285	986	3	276	986	2	274	
October				1	298		3	275		6	294					1	255	
November							3	263	943									
December										5	298		3	281		3	239	
January				2	295		2	252	922									
Average	41	274	973	4	278	977	12	267	942	13	292	986	6	279	986	6	256	
Hopkins:																		
September				1	256	979	20	267	964	2	263	931	7	260	934			
October							1	282	993				1	272	922			
November				1	258	981	2	285	1,026							3	292	
Average	38	271	958	2	257	980	23	278	994	2	263	931	8	266	928	3	292	
Houston:																		
September				1	267					4	297					4	276	
October							2	279		3	314		3	279	964	5	280	
November							3	273	945	1	272	882	2	267	953	5	274	
December							2	284		4	297							
January																2	268	
Average	41	278	929	1	267		7	279	945	12	295	882	5	273	959	16	275	
Howard:																		
September													1	302	1,010			
Average	1	302	1,010										1	302	1,010			
Hunt:																		
September				14	263	977	16	279	1,078	6	292	1,012	12	257	958			
October										1	297	998				7	276	
November				1	247		6	261	1,002	1	283	1,040				7	275	
December							6	270	912	2	286	998	1	261	1,050	3	262	
January							1	238	777	1		907						
Average	85	267	979	15	255	977	29	262	942	11	290	991	13	259	1,004	17	271	
Jack:																		
September				3	242	1,062												
Average	3	242	1,062	3	242	1,062												

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Jackson:																		
September							1	284	958									
November							1	274										
December							1	305		1	303							
Average	4	296	958				3	288	958	1	303							
Jasper:																		
October				3	256	869												
November				1	242	915												
Average	4	249	992	4	249	992												
Jefferson:																		
November													1	313	877			
Average	1	313	877										1	313	877			
Jim Wells:																		
October				1	326	1,002							1	249	1,034			
Average	2	288	1,018	1	326	1,002							1	249	1,034			
Johnson:																		
September										2	296	1,024						
October							1	263								1	244	
January							2	269	901									
Average	6	269	963				3	266	901	2	296	1,024				1	244	

Jones:																		
September				1	295	1,034	5	257	1,036	2	293	1,053	2	293	1,012			
October										4	303	1,021	2	255	974			
November				1	292	1,029				2	302	1,031	2	224	988			
December										6	291	1,055	1	251	847			
January										9	285	1,045	2	247	907			
Average	39	275	1,013	2	294	1,032	5	257	1,036	23	295	1,041	9	254	942			
Kaufman:																		
September				7	258	996	9	265	1,019	2	271	1,055						
October				1	281	1,031							2	260	1,034			
November				2	272	969	5	256	969	1	282	1,088						
December							2	272	1,000									
January										1	285	1,021						
Average	32	268	1,021	10	270	999	16	264	996	4	279	1,055	2	260	1,034			
Kendall:																		
September							1	265	1,002									
Average	1	265	1,002				1	265	1,002									
Kent:																		
September				1	255	1,069												
November													1	276	991			
Average	2	266	1,030	1	255	1,069							1	276	991			
Knox:																		
September				1	237	1,093				1	316	955						
November																1	260	
Average	3	271	1,024	1	237	1,093				1	316	955				1	260	
Lamar:																		
September							5	266	941	2	275	1,010	4	294	865			
October													1	306	907			
November							2	314	910				3	277	877			
December							1	272	974									
January										1	278	958				7	219	983
Average	26	268	951				8	284	942	3	277	984	8	292	883	7	219	983
Lampasas:																		
October													1	256	962			
Average	1	256	962										1	256	962			
Lavaca:																		
October													2	284	983			
November													1	304	939			
December							1	252	901	1	268							
January										1	292	882						
Average	6	277	915				1	252	901	2	280	882	3	294	961			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Lee:																		
September							1	273	1,017									
Average	1	273	1,017				1	273	1,017									
Leon:																		
September				2	254	1,000	1	253	977	1	267		1	308	891	3	256	
October										1	306	993				2	252	
Average	11	273	965	2	254	1,000	1	253	977	2	287	993	1	308	891	5	254	
Liberty:																		
September																1	281	
October													1	240	1,015			
November				1	285	981												
December				1	279	917												
Average	4	268	982	2	282	949							1	240	1,015	1	281	
Limestone:																		
September				1	268	960	1	266	1,034	1	291	1,002						
October				2	254	945	1	280	1,002	2	286	986	2	252	1,034	2	276	
November				1	255	981							1	290	936			
December										1	288							
Average	15	273	990	4	259	962	2	273	1,018	4	288	994	3	271	985	2	276	
Live Oak:																		
September							1	275	1,005									
January										1	306	879						
Average	2	291	942				1	275	1,005	1	306	879						

Lubbock:																		
September										2	348	958						
October				1	286								1	284	1,036			
November				4	314	981												
December				3	290	988				3	301	1,002						
January				3	295	960							1	289	1,045			
Average	18	303	999	11	296	976				5	325	980	2	287	1.041			
Lyon:																		
October				1	276	1,015				1	318	1,026						
November				1	283	983				1	309	998						
December				1	300	931				2	258	958						
January													2	273	981			
Average	9	285	985	3	286	980				4	295	994	2	273	981			
McCulloch:																		
November																1	257	
Average	1	257														1	257	
McLennan:																		
September				5	272	988	5	258	1,021	2	291	962	2	257		3	262	
October							3	267	1,043	5	293		2	275	936	4	276	993
November							7	275	1,026	1	291					4	253	915
December				4	268	877	5	266	979	2	297	1,062	2	282		9	244	1,029
January				1	292		1	268	941	2	282					4	257	922
Average	73	273	970	10	277	933	21	267	1,002	12	291	1,012	6	271	936	24	258	965
Madison:																		
September							1	313	939	1	283							
October										1	294					2	270	
November							1	281										
December							1	277		1	283					1	257	
Average	9	280	939				3	290	939	3	287					3	264	
Marion:																		
September							2	295	934	3	250	910	2	293	874			
October							1	289	917	4	276	939						
November										1	275							
Average	13	284	908				3	292	926	8	267	925	2	293	874			
Mason:																		
October							1	293	979									
Average	1	293	979				1	293	979									

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Matagorda:																		
September				1	277													
October				1	275	939				1	285							
November							1	288										
December										1	268							
Average	5	280	939	2	276	939	1	288		2	277							
Maverick:																		
October										6	295							
Average	6	295								6	295							
Medina:																		
September							1	301	979									
Average	1	301	979				1	301	979									
Milam:																		
September				2	262	974	2	265	1,055	2	295	1,031	1	283	960			
October				2	265	955							2	284	1,007			
November				3	266	958	3	248	1,010									
December				6	265	958												
January				3	265	936				1	243	1,021						
Average	27	269	1,000	16	265	956	5	257	1,033	3	269	1,026	3	284	984			
Mills:																		
September				1	271													
Average	1	271		1	271													

Mitchell:																		
September													1	291	998			
October										1	288							
December													1	301	1,038	1	252	
Average	4	279	1,018							1	288		2	296	1,018	1	252	
Montague:																		
October							1	265										
November							1	308										
Average	2	287					2	287										
Montgomery:																		
September				2	283	974				1	257							
October													2	270	967			
December				1	250	996												
Average	6	265	976	3	267	985				1	257		2	270	967			
Morris:																		
September										1	277	1,015						
October							1	310	801				2	276	831			
November							1	315	834									
January													1	290	829			
Average	6	291	888				2	313	818	1	277	1,015	3	283	830			
Motley:																		
September				1	271	1,059				2	331	1,000						
October				3	278	974	1	325	1,038	1	301	979	4	313	1,038			
November				3	307	955												
December				4	282	981	1	264	998	2	273	1,024						
January				3	278	903	2	244	1,017									
Average	27	294	1,008	14	283	974	4	278	1,018	5	302	1,001	4	313	1,038			
Nacogdoches:																		
September				1	265	979												
October				1	265	915							3	268	974			
November				2	293	962												
December										1	295							
Average	8	279	963	4	274	952				1	295		3	268	974			
Navarro:																		
September				1	251	1,012	6	267	1,031	4	296	1,081	2	246	945	2	261	
October				2	284	986	4	257	1,029	1	286	993	4	272	1,010	1	259	
December							2	279	972									
January				5	284	981	1	240	926				1	247	943	1	230	
Average	37	266	997	8	273	993	13	261	990	5	291	1,037	7	255	966	4	250	

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Nolan:																		
September										1	275	1,074						
October										2	332	917						
January													3	279	936			
Average	6	292	966							3	304	996	2	279	936			
Nueces:																		
September													1	262		5	260	
October				1	257	948							1	262	1,015			
December				1	238	1,005										1	255	
Average	10	256	996	2	248	977							2	262	1,015	6	258	
Palo Pinto:																		
October							1	284	1,093									
Average	1	284	1,093				1	284	1,093									
Panola:																		
October													2	314	938			
January				1	282								1	283	882			
Average	4	291	910	1	282								3	299	910			
Parker:																		
September							1	288	1,026							1	289	991
December				2	258	1,000										1	274	
January				1	262													
Average	6	270	1,006	3	240	1,000	1	288	1,026							2	282	991

Polk:																		
September				2	289	1,038	1	310	915	1	333		1	262	979			
October				1	293					1	333		4	287	983			
November							1	294										
December							1	247	903	1	308							
Average	14	293	976	3	291	1,038	3	284	909	3	321		5	275	981			
Pecos:																		
September				1	282													
Average	1	282		1	282													
Rains:																		
September				5	264	977	1	276	979									
Average	6	270	978	5	264	977	1	276	979									
Red River:																		
September				2	297	1,000	7	282	926	1	252	950						
October				2	292					1	281	950	2	276	863			
December							1	334	877									
January							1	330	931									
Average	17	288	931	4	295	1,000	9	315	911	2	267	950	2	276	863			
Refugio:																		
September													2	284		1	254	
October													1	293	1,081	1	255	
November				2	262	967												
January																1	300	
Average	8	274	1,024	2	262	967							3	289	1,081	3	270	
Robertson:																		
September				1	235	972	2	277	1,055							1	312	934
October				3	250	960							1	274	1,012	3	283	924
November				1	268	934												
December				1	280	977												
January				1	287													
Average	14	278	984	7	264	961	2	277	1,055				1	274	1,012	4	298	929
Rockwall:																		
September							6	258	1,019	1		934	1	267				
October				2	251	969												
November							2	247	903									
December							1	274	929									
Average	13	259	951	2	251	969	9	260	950	1		934	1	267				

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
Runnels:		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
October										2	290		1	265	979			
November				1	333	958				1	275	960	1	281	1,038			
December																2	276	
January				1	271								1	273	972	3	274	
Average	13	283	971	2	302	958				3	283	960	3	273	996	5	275	
Rusk:																		
September				5	277	998												
October				1	284	910							4	279	941	1	279	
November				1	288	941												
December				1	254	915												
January				3	281	905												
Average	16	278	937	11	277	932							4	279	941	1	279	
Sabine:																		
October				2	259	929												
November				1	265	943												
Average	3	362	936	3	262	936												
San Augustine:																		
October				3	272	931												
November				5	281	924							1	285	972			
December				2	294	924												
Average	11	284	949	10	282	926							1	285	972			
San Jacinto:																		
September							1	307	1,019	1	309							
October				1	306					1	330		1	296	1,015			
December										1	315							
Average	6	307	1,017	1	306		1	307	1,019	3	318		1	296	1,015			

San Patricio:																		
October				2	251	993												
Average	2	251	993	2	251	993												
San Saba:																		
September				1	290													
October							1	282	1,105									
Average	2	286	1,105	1	290		1	282	1,105									
Schleicher:																		
September				2	258	1,048												
November				1	310	1,017												
January				2	301	929												
Average	5	290	998	5	290	998												
Scurry:																		
November										1	291							
December										1	284	939						
Average	2	288	939							2	288	939						
Shelby:																		
September				1	286	948	4	262	926	1	272	962	2	300	915			
October				4	268	988							3	289	996			
Average	15	277	953	5	277	968	4	262	926	1	272	962	5	295	956			
Smith:																		
September				3	271		2	258	962				1	277	882			
October													2	284	981			
January				1	312													
Average	9	277	947	4	292		2	258	962				3	281	932			
Somervell:																		
September				1	280													
Average	1	280		1	280													
Stephens:																		
September							1	308	1,129									
December										1	273	1,015						
Average	2	291	1,072				1	308	1,129	1	273	1,015						
Stonewall:																		
September				1	247	1,040												
November										1	301	991	1	314	825			
Average	3	287	952	1	247	1,040				1	301	991	1	314	825			

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Tarrant:																		
September				1	263		2	270	983	6	285	1,055	1	269	934	3	279	
October				3	264		1	267		1	305					2	263	
November							1	257	893				1	279	1,050			
December							3	281	967							1	276	
January				1	272													
Average	27	276	998	5	267		7	269	948	7	295	1,055	2	274	992	6	273	
Taylor:																		
September				1	252	1,124				1	299		1	300	1,019			
October										1	286		1	281	974			
January										1	277	1,057	1	273	960			
Average	7	275	1,055	1	252	1,124				3	287	1,057	3	285	984			
Terry:																		
November				3	300	964												
December				3	287	945												
January				1	258	825												
Average	7	282	911	7	282	911												
Titus:																		
September							3	312	1,010									
November										1	291	958						
December										1	289	1,064						
Average	5	304	1,011				3	312	1,010	2	295	1,011						
Tom Green:																		
December																1	281	
Average	1	281														1	281	

Travis:																		
September				4	259	988	2	248	1,026							2	282	
October							1	235	1,036	1	314		4	283	1,015			
December				1	254	945												
January							1	330	784									
Average	16	281	977	5	257	967	4	271	949	1	314		4	283	1,015	2	282	
Trinity:																		
September				1	253	945												
October				2	261	977												
December										1	273							
Average	4	265	961	3	257	961				1	273							
Tyler:																		
September				1	258	886												
Average	1	258	886	1	258	886												
Upshur:																		
September				1	273	926	2	298	967	1	279	1,007						
October							1	276	858									
January										1	264	1,034						
Average	6	277	953	1	273	926	3	287	913	2	272	1,021						
Upton:																		
December										1	254	1,050						
Average	1	254	1,050							1	254	1,050						
Van Zandt:																		
September				1	269	1,017	1	255	1,050	1	276	979						
December							1	278	962									
Average	4	271	1,001	1	269	1,017	2	267	1,006	1	276	979						
Victoria:																		
September										1	247		1	294		1	269	
October				1	254	893												
November				1	247	1,000												
December										1	283							
Average	6	270	947	2	251	947				2	265		1	294		1	269	
Walker:																		
September				2	277	1,019				1	278							
October				5	275	983	1	290		1	307					1	276	
December										1	308					1	267	
January				1	277													
Average	14	284	1,001	8	276	1,001	1	290		3	298					2	272	

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Waller:																		
September							1	272		1	296					2	284	
October							1	271		1	296		1	277	960	1	262	
November							1	285										
December										2	293					1	264	
Average	12	280	960				3	276		4	295		1	277	960	4	270	
Ward:																		
September							2	295	941									
January																1	292	
Average	3	294	941				2	295	941							1	292	
Washington:																		
September							1	275	977									
October													1	301	969			
Average	2	288	973				1	275	977				1	301	969			
Webb:																		
September							1	314	1,045	1	257	1,010						
Average	2	286	1,028				1	314	1,045	1	257	1,010						
Wharton:																		
September							2	278	1,017	1	273					1	279	
October																1	314	877
December										2	289							
Average	7	285	947				2	278	1,017	3	281					2	297	877

Wheeler:																		
October							1	314	1,057									
November							2	305	1,005									
December							1	268	969									
January							1	235	939									
Average	5	306	993				5	306	993									
Wichita:																		
September				1	241	1,045				1	280	1,074						
October							1	295	1,093									
November							1	288	1,053				1	308	1,034			
December										1	282	1,038						
Average	6	281	1,052	1	241	1,045	2	292	1,073	2	281	1,056	1	308	1,034			
Wilbarger:																		
September							3	275	1,045									
October				1	254	1,002												
November													1	315	998			
December				1	276	1,057				1	298	1,038				1	267	
January													1	263	962			
Average	9	279	1,023	2	265	1,030	3	275	1,045	1	298	1,038	2	289	980	1	267	
Williamson:																		
September													3	273	1,005			
October													1	269	996			
November										3	268	1,048	3	266	1,048			
December							1	302	950	5	263	1,026						
January										1	247	1,050						
Average	17	277	1,002				1	302	950	9	259	1,041	7	269	1,016			
Wilson:																		
November													1	281	1,053			
Average	1	281	1,053										1	281	1,053			
Wise:																		
September				2	256	929	1	285	998	2	294	1,010				1	254	
October				2	261		1	265								1	276	
November				3	263	936												
December							1	295		1	296	1,045				2	267	
January				1	274													
Average	18	277	1,003	8	264	983	3	282	998	3	295	1,028				4	266	
Wood:																		
September				2	287	896	2	261	955	3	283	972	1	308	784			
November													1	308	912	1	299	
Average	10	288	918	2	287	896	2	261	955	3	283	972	2	308	848	1	299	

TABLE VI.—*Yields of oil and meal, by counties, as compiled from analyses*—Continued.

TEXAS—Continued.

BY COUNTIES AND MONTHS—Continued.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Young:																		
September				5	258	1,064	1	263	1,129	1	265	979	1	310	1,040			
October							1	295	1,081									
November				1	266													
December							1	318	1,001							1	266	
January				1	245	1,015												
Average	13	278	1,032	7	256	1,040	3	292	1,070	1	265	979	1	310	1,040	1	266	

VIRGINIA.

BY COUNTIES.

County.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	32	327	927	2	341	898	21	320	914	3	332	916	1	338	944	5	330	956
Brunswick	7	334	920	1	333	852	4	349	850	1	321	1,016				1	333	960
Essex	1	363	956	1	363	956												
Isle of Wight	2	274	916				2	274	916									
Nansemond	4	312	934				2	304	921							2	320	946
Southampton	16	328	931	1	348	944	12	310	929	1	314	871	1	338	944	1	328	969
Sussex	2	349	905							1	360	861				1	338	950

By Counties and Months.

County and month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Brunswick:																		
September										1	321	1,016						
October				1	333	852										1	333	960
December							1	358	893									
January							3	339	807									
Average	7	334	920	1	333	852	4	349	850	1	321	1,016				1	333	960
Essex:																		
November							1	363	956									
Average	1	363	956				1	363	956									
Isle of Wight:																		
November							1	277	941									
December							1	270	890									
Average	2	274	916				2	274	916									
Nansemond:																		
September																1	311	884
October							1	335	940							1	329	1,007
November							1	272	902									
Average	4	312	934				2	304	921							2	320	946
Southampton:																		
September										1	314	871						
October							3	321	950				1	338	944	1	328	969
November				1	348	944	2	321	918									
December							4	305	921									
January							3	293	925									
Average	16	328	944	1	348	944	12	310	929	1	314	871	1	338	944	1	328	969
Sussex:																		
November																1	338	950
December										1	360	861						
Average	2	349	906							1	360	861				1	338	950

TABLE VII.—*Yields of oil and meal, by months, as compiled from analyses.*

UNITED STATES.

Month.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
United States	46,029	311	982	13,997	296	1,025	8,780	316	967	6,576	318	955	7,895	314	981	8,781	312	979
September	12,605	311	985	3,816	280	1,024	1,834	311	979	2,043	319	957	2,953	320	965	1,959	315	988
October	12,676	312	987	3,480	305	1,028	2,346	316	981	1,436	319	967	3,161	316	975	2,253	314	985
November	9,490	315	987	3,134	302	1,026	2,430	322	966	1,176	318	963	988	315	997	2,062	315	978
December	6,674	309	977	1,884	296	1,029	1,292	313	961	1,414	314	950	598	311	980	1,486	312	962
January	4,584	307	973	1,683	298	1,014	878	310	952	507	313	942	195	306	973	1,321	305	977

ALABAMA.

State	5,259	320	965	1,465	306	1,019	553	324	943	353	331	914	1,385	316	980	1,503	321	968
September	1,516	323	965	451	303	1,009	195	330	958	138	343	910	442	320	964	290	319	982
October	1,498	322	962	376	307	1,022	162	326	949	92	338	916	475	319	963	393	318	962
November	967	320	970	228	306	1,020	137	327	943	61	329	929	223	313	984	318	323	973
December	849	315	971	284	305	1,024	25	317	948	50	320	928	203	309	996	287	324	960
January	429	318	957	126	308	1,020	34	322	918	12	324	889	42	318	995	215	319	963

ARIZONA.

State	5	313	1,054							5	313	1,054						
September	3	317	1,064							3	317	1,064						
October	1	302	998							1	302	998						
November	1	319	1,099							1	319	1,099						

ARKANSAS.

State	3,987	306	1,010	1,668	290	1,055	1,214	318	971	417	308	1,025	500	311	981	188	307	1,018
September	962	307	1,016	430	283	1,057	103	313	982	221	310	1,027	74	317	982	134	311	1,030
October	1,123	310	1,023	497	388	1,067	396	322	985	45	303	1,050	159	318	979	26	317	1,032
November	972	309	1,015	364	296	1,059	345	320	970	59	306	1,078	188	316	985	16	307	995
December	602	309	995	226	295	1,051	240	318	963	72	308	994	63	301	979	1	323	988
January	328	297	999	151	291	1,042	130	316	956	20	312	976	16	291	978	11	275	1,043

CALIFORNIA.

State	16	323	1,133	13	322	1,142	1	346	1,140	2	316	1,154	.....	.....	.....	.....	.....	.....
November	2	326	1,218	1	330	1,295	.....	.....	.....	1	321	1,140	.....	.....	.....	.....	.....	.....
December	5	325	1,128	3	319	1,077	1	346	1,140	1	311	1,168	.....	.....	.....	.....	.....	.....
January	9	317	1,054	9	317	1,054	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

FLORIDA.

State	352	325	1,021	80	315	1,090	145	334	1,029	14	336	938	72	319	1,021	41	326	979
September	120	326	996	18	311	1,044	62	324	1,017	5	350	934	25	324	994	10	319	991
October	101	324	1,021	32	316	1,080	29	334	1,011	6	330	980	26	312	1,022	8	330	1,012
November	66	331	1,035	26	324	1,085	26	347	1,026	.....	.....	.....	13	319	1,063	1	335	969
December	55	324	1,003	1	295	1,111	25	335	1,059	3	329	901	8	320	1,004	18	340	941
January	10	322	1,048	3	329	1,128	3	330	1,034	.....	.....	.....	.....	.....	.....	4	308	981

GEORGIA.

State	14,083	323	943	4,194	307	973	2,359	317	943	2,572	330	897	2,343	323	972	2,615	327	929
September	4,474	330	940	1,128	302	961	678	320	952	783	338	880	1,215	324	964	670	329	941
October	3,589	323	933	1,008	310	973	561	318	937	624	336	881	788	324	956	608	328	920
November	2,737	322	947	1,062	308	980	582	320	943	453	329	909	180	323	978	460	330	926
December	1,988	320	950	521	307	982	309	316	949	555	325	908	124	322	979	479	330	931
January	1,295	318	944	475	307	970	229	310	935	157	324	905	36	321	982	398	320	925

TABLE VII.—*Yields of oil and meal, by months, as compiled from analyses*—Continued.

KENTUCKY.

State.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	27	318	1,022	8	299	1,087	.10	336	917	.....	.....	.....	8	324	1,047	1	303	978
September	6	323	1,029	3	279	1,077	1	340	975	.....	.....	.....	2	349	1,035	.....	.....	.....
October	8	311	1,086	4	307	1,148	.....	.....	.....	.....	.....	.....	4	314	1,023	.....	.....	.....
November	10	333	1,018	1	312	1,035	8	341	915	.....	.....	.....	1	345	1,105	.....	.....	.....
December	1	326	861	.....	.....	.....	1	326	861	.....	.....	.....	.....	.....	.....	.....	.....	.....
January	2	296	1,002	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	289	1,026	1	303	978

LOUISIANA.

State	2,104	309	1,038	515	300	1,109	605	314	1,061	550	312	1,009	293	308	1,000	141	309	1,012
September	598	312	1,033	145	309	1,084	121	304	1,057	125	317	1,015	149	313	1,000	58	315	1,008
October	512	303	1,032	164	309	1,081	172	303	1,046	62	301	1,011	80	313	985	34	303	1,035
November	455	308	1,048	73	303	1,109	139	313	1,081	170	308	993	49	302	1,029	24	312	1,027
December	330	308	1,033	70	291	1,127	108	314	1,052	130	316	1,030	9	312	986	13	305	968
January	209	312	1,046	63	290	1,145	65	335	1,070	63	318	997	6	307	998	12	309	1,022

MISSISSIPPI.

State	2,351	313	994	1,439	303	1,042	370	324	972	185	319	972	188	310	992	169	311	992
September	777	315	980	449	300	1,040	104	321	968	126	318	942	45	315	961	53	322	988
October	554	314	1,009	367	299	1,043	89	325	1,005	22	324	1,002	42	313	987	34	311	1,010
November	551	316	994	319	306	1,056	127	334	965	17	322	958	53	309	1,004	35	308	988
December	261	312	1,007	160	304	1,040	32	325	994	9	319	1,003	31	307	1,005	29	306	994
January	208	310	978	144	306	1,029	18	316	926	11	314	953	17	306	1,004	18	309	980

MISSOURI.

State	338	306	983	151	287	1,031	19	338	940	15	309	958	146	310	986	7	304	994
September	43	292	1,041	32	264	1,072	.....	.....	.....	2	298	1,048	9	318	1,004	.....	.....	.....
October	124	310	1,000	51	288	1,034	7	324	996	5	291	994	57	324	968	4	322	1,008
November	79	315	987	13	295	1,055	6	360	942	3	318	953	54	314	1,006	3	286	979
December	77	312	964	44	302	1,056	6	331	882	3	313	912	24	302	1,004	.....	.....	.....
January	15	299	923	11	285	938	.....	.....	.....	2	323	883	2	290	947	.....	.....	.....

NEW MEXICO.

State	2	353	1,045	1	362	.....	.....	.....	.....	1	344	1,045	.....	.....	.....	.....	.....	.....
October	1	362	.....	1	362	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November	1	344	1,045	.....	.....	.....	.....	.....	.....	1	344	1,045	.....	.....	.....	.....	.....	.....

NORTH CAROLINA.

State	4,065	327	937	1,454	312	975	777	318	905	578	338	896	575	339	963	681	331	947
September	766	330	939	311	309	984	46	323	911	119	344	882	190	342	964	100	334	955
October	1,266	331	935	398	313	979	250	222	903	138	347	898	358	340	947	122	331	951
November	912	331	946	417	319	965	278	322	903	88	343	907	14	341	981	115	331	973
December	593	322	936	172	308	975	113	311	906	154	330	905	9	329	946	145	330	947
January	528	323	930	156	312	974	90	311	901	79	324	886	4	341	979	199	329	909

OKLAHOMA.

State	906	290	995	190	263	1,018	207	286	1,005	190	287	991	136	308	946	183	304	1,019
September	246	282	993	84	254	1,025	35	276	1,031	82	272	988	24	309	901	21	297	1,017
October	220	288	1,012	42	256	1,037	58	291	1,038	28	291	999	32	303	971	60	298	1,023
November	149	299	1,003	11	270	998	62	293	999	14	294	1,004	26	309	978	36	329	1,040
December	179	292	984	45	267	1,029	28	291	989	38	290	977	32	315	927	36	298	998
January	112	288	984	8	270	1,002	24	277	966	28	286	988	22	306	953	30	299	1,019

SOUTH CAROLINA.

State	9,277	325	940	1,762	305	981	1,794	320	940	1,029	333	911	1,737	333	963	2,955	337	922
September	2,223	330	934	485	300	967	258	325	934	252	340	901	669	340	956	559	343	911
October	2,975	328	938	314	306	985	512	320	930	278	339	905	976	337	954	895	338	914
November	1,863	327	950	440	307	982	460	323	940	210	335	915	58	333	980	695	337	934
December	1,138	322	947	197	305	992	316	313	945	195	325	913	21	333	958	409	335	928
January	1,078	320	949	326	305	979	248	317	951	94	324	922	13	321	969	397	333	923

TABLE VII.—*Yields of oil and meal, by months, as compiled from analyses*—Continued.

TENNESSEE.

State.	Total samples.	5-year average yield of—		Crop season.														
				1918–19			1917–18			1916–17			1915–16			1914–15		
		Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.	Samples.	Oil.	Meal.
		Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
State	1,323	305	981	623	293	1,032	255	317	917	192	317	964	185	308	973	68	292	1,019
September	183	308	989	121	279	1,048	18	313	955	32	314	978	1	334	937	11	302	1,027
October	273	309	996	143	294	1,052	38	327	942	35	331	987	46	313	989	11	289	1,015
November	432	312	981	109	304	1,041	166	322	894	52	321	963	88	312	998	17	303	1,008
December	249	297	961	98	297	1,012	24	311	882	61	307	926	45	292	982	21	278	999
January	186	299	977	152	291	1,006	9	313	911	12	313	967	5	290	956	8	288	1,044

TEXAS.

State	1,984	280	971	456	276	968	482	278	979	481	290	989	335	282	991	230	274	948
September	697	280	992	162	265	1,005	214	274	1,008	158	288	977	110	286	953	53	276	1,017
October	441	282	982	88	274	978	72	280	1,025	101	301	986	122	275	979	58	280	937
November	307	284	968	72	283	967	102	284	987	49	293	986	42	285	982	42	275	919
December	353	278	969	66	275	950	66	278	965	144	287	1,003	29	285	996	48	267	928
January	186	275	944	68	282	937	28	263	908	29	281	992	32	279	944	29	270	940

VIRGINIA.

State	32	326	906	2	341	898	21	316	910	3	339	903	1	338	944	5	326	938
September	3	315	914	.....	.....	.....	.....	.....	.....	2	318	944	.....	.....	.....	1	311	884
October	9	332	930	1	333	852	4	328	945	.....	.....	.....	1	338	944	3	330	979
November	7	331	941	1	348	944	5	308	929	.....	.....	.....	.....	.....	.....	1	338	950
December	7	336	881	.....	.....	.....	6	311	901	1	360	861	.....	.....	.....	.....	.....	.....
January	6	316	866	.....	.....	.....	6	316	866	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE VIII.—*Variation of yields of oil and meal on same market.*

Origin.	Date sold.	Oil.	Meal.
	1918	*Pounds.*	*Pounds.*
Jefferson County, Ark.:			
Althemier	Dec. 13	256	947
Do	do	273	1,032
Do	do	283	1,105
Do	do	295	1,169
Ouachita County, Ark.:			
Camden	Nov. 7	255	1,055
Do	do	262	1,092
Do	do	263	988
Do	do	276	1,036
Do	do	286	1,045
Do	do	302	1,073
Mississippi County, Ark.:			
Osceola	Nov. 18	314	1,042
Do	do	318	1,029
Do	do	329	1,032
Do	Nov. 21	334	1,080
Do	do	338	1,118
Do	Nov. 24	297	921
Pulaski County, Ark.:			
Scott	Nov. 17	287	988
Do	do	290	893
Do	Nov. 18	281	998
Do	do	321	937
Do	Nov. 20	264	1,051
Do	do	303	985
Burke County, Ga.:			
Waynesboro	Dec. 11	278	903
Do	do	301	966
Do	do	305	959
Do	do	315	890
Do	do	333	925
Clark County, Ga.:			
Athens	Oct. 24	297	921
Do	do	307	845
Do	do	328	912
Franklin County, Ga.:			
Lavonia	Jan. 29	291	909
Do	do	312	909
Do	do	312	915
Burke County, Ga.:			
Waynesboro	Sept. 5	300	804
Do	Sept. 6	319	814
Do	do	324	864
Do	Sept. 7	327	1,007
Do	Sept. 9	309	903
Do	Sept. 10	324	966
Do	Sept. 11	291	991
Do	do	301	890
Do	do	314	865
Do	do	333	896
Dougherty County, Ga.:			
Albany	Sept. 7	260	944
Do	do	282	1,032
Do	do	302	1,010
Do	do	304	934
Do	Sept. 10	307	959
Do	Sept. 11	308	985
Do	Sept. 12	313	982
Do	Sept. 13	294	931
Do	do	303	963
Do	do	304	966
Do	do	319	925
Lee County, Miss.:			
Tupela	Oct. 2	280	1,026
Do	do	292	1,042
Do	do	295	1,020
Do	do	298	1,118
Do	do	336	1,055
Sunflower County, Miss:			
Drew	Nov. 3	321	1,064
Do	do	323	1,067
Do	do	323	1,089
Do	do	324	1,080
Do	do	324	1,089
Washington County, Miss.:			
Greenville	Sept. 1	284	937
Do	do	297	950
Do	do	305	1,026
Do	do	313	994
Do	do	317	928
Do	do	323	922
Do	do	323	947
Sunflower County, Miss:			
Drew	Nov. 18	287	997
Do	do	293	1,054
Do	do	298	975
Do	do	305	978
Do	Nov. 21	290	1,089
Do	do	295	1,093
Do	do	304	1,115
Do	Nov. 23	322	1,051
Do	do	325	1,054
Tallahatchie County, Miss.:			
Charleston	Nov. 24	298	1,064
Do	do	318	1,039
Do	Nov. 25	276	1,048
Do	do	294	953
Do	do	307	1,007
Do	Nov. 26	302	1,111
Do	Nov. 27	283	1,020
Do	Nov. 30	314	1,004
Mecklenburg County, N. C.:			
Charlotte	Sept. 21	284	988
Do	do	289	985
Do	do	295	960
Do	do	295	978
Do	do	302	896
Do	do	314	998
Do	do	327	966
Do	do	329	947
Do	do	333	921
Do	do	342	937
Do	do	350	934
Scotland County, N. C.:			
Gibson	Nov. 26	283	1,039
Do	do	289	1,105
Do	do	293	1,070
Do	do	296	1,096
Cumberland County, N. C.:			
Fayetteville	Nov. 9	309	950
Do	do	330	956
Do	Nov. 11	276	959
Do	do	294	941
Do	Nov. 12	296	931
Do	Nov. 13	281	925
Do	do	288	925
Do	Nov. 14	316	959
Do	Nov. 15	295	902
Union County, N. C.:			
Union	Oct. 5	305	918
Do	Oct. 9	295	950
Do	do	316	890
Do	do	325	979
Do	do	334	950
Do	Oct. 10	311	931
Do	do	313	940
Do	do	320	921
Do	do	325	874
Do	Oct. 11	309	940
Do	do	313	1,048
Do	do	325	1,010
Barnwell County, S. C.:			
Allendale	Sept. 26	276	978
Do	do	302	903
Do	do	314	922
Do	do	318	921
Do	do	323	1,029
Do	do	329	909

TABLE VIII.—*Variation of yields of oil and meal on same market*—Continued.

Origin.	Date sold.	Oil.	Meal.
		Pounds.	*Pounds.*
Berkeley County, S. C.:	1918		
Monk's Corner	Nov. 16	313	896
Do	do	316	1,093
Do	do	318	966
Calhoun County, S. C.:			
St. Matthews	Oct. 16	285	966
Do	do	301	827
Do	do	327	1,004
Charleston County, S. C.:			
Charleston	Oct. 29	301	947
Do	do	305	874
Do	do	324	1,013
Do	do	340	960
Lexington County, S. C.:			
Batesburg	Oct. 21	281	1,048
Do	do	284	979
Do	do	287	1,055
Do	do	301	1,074
Do	do	302	1,045
Do	do	325	1,016
Darlington County, S. C.:			
Darlington	Sept. 13	288	1,020
Do	Sept. 14	280	975
Do	Sept. 16	279	906
Do	do	297	950
Do	Sept. 18	302	1,051
Dillon County, S. C.:			
Latta	Sept. 10	289	1,036
Do	do	295	1,001
Do	do	295	1,042
Do	Sept. 11	280	1,017
Do	do	298	1,001
Do	Sept. 12	283	1,064
Do	Sept. 13	280	1,013
Do	do	282	994
Orangeburg County, S. C.:			
Springfield	Nov. 14	276	1,004
Do	do	279	979
Do	Nov. 15	274	1,010
Do	Nov. 16	283	979
Do	Nov. 18	296	982
Do	do	322	1,004
Do	Nov. 19	290	944
Do	Nov. 20	278	978
Do	do	291	931
Do	do	310	997
Lincoln County, N. C.:	1917.		
Lincolnton	Nov. 30	286	915
Do	do	299	940
Do	do	300	890
Do	do	303	979
Do	do	312	921
Scotland County, N. C.:			
Elmore	Oct. 14	308	865
Do	do	311	890
Do	do	314	865
Do	do	314	918
Union County, N. C.:			
Monroe	Oct. 17	306	817
Do	do	314	918
Do	do	308	836
Do	do	326	906
Do	do	336	909
Cumberland County, N. C.:			
Fayettville	Oct. 10	288	899
Do	Oct. 11	285	842
Do	do	291	921
Do	Oct. 13	311	890
Do	do	316	975
Do	Oct. 15	314	918
Do	Oct. 16	297	887
Hempstead County, Ark.:	1916		
Hope	Sept. 10	280	1,035
Do	do	287	985
Do	do	296	1,020
Do	do	297	1,016
Do	do	298	1,004
Do	do	301	909
Do	do	304	903
Do	do	308	1,007
Do	do	310	950
Do	do	315	960
Do	do	315	1,036
Do	do	321	991
Do	do	321	998
Do	do	321	1,007
Do	do	322	1,001
Do	do	327	928
Do	do	331	985
Do	do	332	1,035
Do	do	333	966
Do	do	334	988
Do	do	337	975
Bartow County, Ga.:			
Cartersville	Oct. 4	333	921
Do	do	344	874
Do	do	348	839
Do	do	350	855
Do	Nov. 19	323	947
Do	do	329	827
Do	do	332	887
Do	do	338	928
Do	do	338	953
Do	Nov. 26	307	874
Do	do	311	883
Do	do	318	877
Do	do	322	890
Do	do	326	931
Do	Sept. 17	350	884
Do	do	366	855
Do	Sept. 18	355	833
Do	Sept. 19	330	858
Do	Sept. 20	341	925
Do	Sept. 21	353	861
Do	Sept. 23	355	880
Do	do	360	855
Hancock County, Ga.:			
Devereaux	Sept. 22	335	887
Do	Sept. 23	348	845
Do	do	349	858
Do	Sept. 24	336	852
Do	Sept. 25	327	849
Do	Sept. 28	338	864
Terrell County, Ga.:			
Dawson	Sept. 25	333	969
Do	Sept. 27	338	906
Do	do	341	909
Do	do	352	953
Do	do	370	915
Do	Sept. 28	344	855
Do	do	344	807
Do	do	352	858
Do	do	352	953
Do	Sept. 30	321	880
Bartow County, Ga.:	1915.		
Cartersville	Oct. 18	322	940
Do	do	324	903
Do	do	337	918
Do	do	348	944
Do	do	356	922
Taliaferro County, Ga.:			
Crawfordsville	Oct. 22	311	915
Do	do	322	918
Do	do	326	899
Do	do	327	893
Do	do	327	928
Do	do	330	909
Do	do	330	921
Do	do	331	921
Do	do	343	922

TABLE VIII.—*Variation of yields of oil and meal on same market*—Continued.

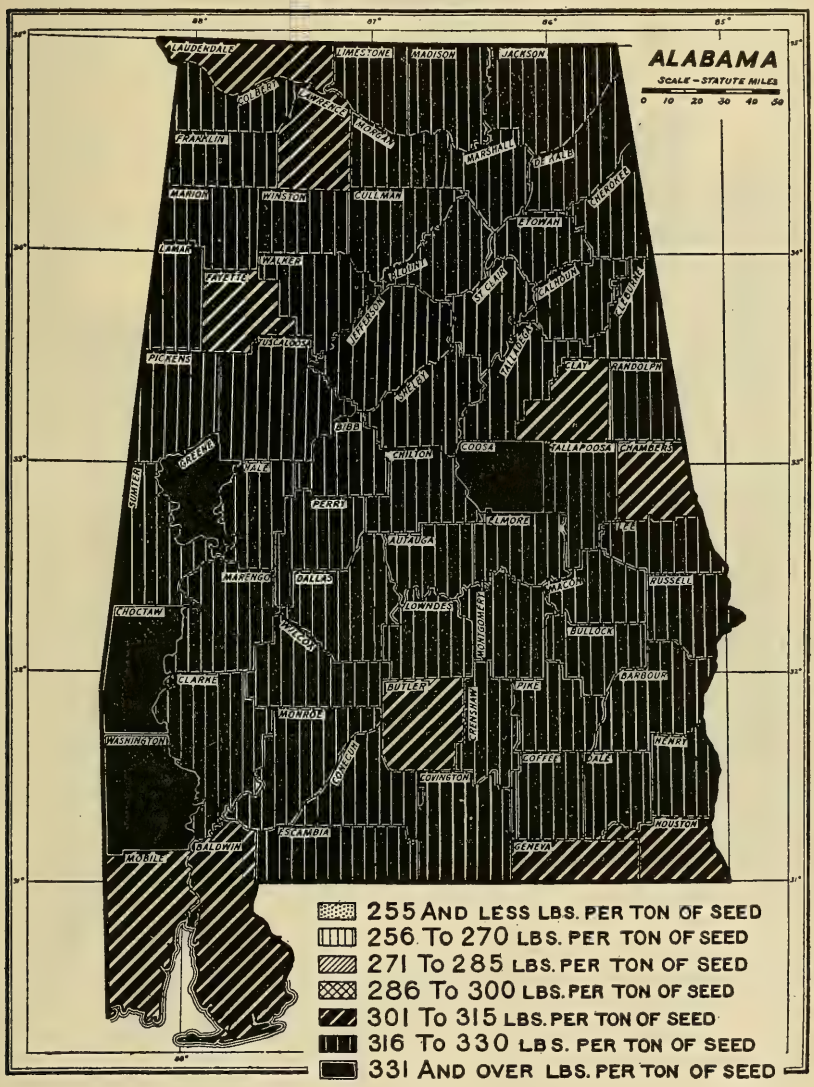
Origin.	Date sold.	Oil.	Meal.
Terrell County, Ga.:	1915	*Pounds.*	*Pounds.*
Dawson	Aug. 14	302	1,007
Do	do	303	1,061
Do	do	309	988
Do	do	309	1,001
Do	do	314	1,058
Do	do	314	1,064
Do	do	317	963
Do	Aug. 15	327	982
Do	Aug. 16	348	915
Do	Aug. 18	299	988
Do	do	303	1,004
Do	do	306	877
Do	do	309	1,105
Do	do	320	991
Do	do	338	1,010
Chesterfield County, S. C.:			
Ruby	Sept. 27	325	969
Do	do	332	956
Do	do	337	978
Do	do	338	966
Dillon County, S. C.:			
Little Rock	Sept. 24	361	966
Do	do	367	956
Do	do	374	944
Greenwood County, S. C.:			
Greenwood	Sept. 27	334	1,039
Do	do	344	1,055
Do	do	351	915
Do	do	358	982
Do	do	363	956
Do	do	366	959
Do	do	384	978
Marlboro County, S. C.:			
Clio	Oct. 16	339	940
Do	do	340	975
Do	do	343	959
Do	do	344	979
Do	do	347	956
Do	do	349	940
Do	do	349	959
Do	do	350	1,029
Do	do	351	1,016
Do	do	356	978
Do	do	359	994
Do	do	361	1,029
Darlington County, S. C.:			
Darlington	Oct. 25	353	960
Do	Oct. 26	311	953
Do	Oct. 27	305	941
Do	do	312	979
Do	do	314	937
Do	do	329	979
Do	Oct. 30	311	991
Do	do	320	991
Do	do	322	960
Do	do	336	969
Do	do	340	979
Do	do	327	1,058
Greenwood County, S. C.:			
Greenwood	Sept. 13	344	1,004
Do	do	347	1,004
Do	Sept. 15	331	906
Do	Sept. 16	337	985
Do	do	344	972
Do	do	367	1,013
Do	Sept. 18	350	931
Do	do	352	985
Do	do	359	1,026
Do	do	371	972
Do	Sept. 19	333	922
Greenwood County, S. C.—Continued.	1915	*Pounds.*	*Pounds.*
Greenwood	Sept. 19	335	931
Do	do	341	1,010
Do	do	353	1,016
Monroe County, Ark.:	1914.		
Holly Grove	Sept. 4	314	997
Do	do	314	1,001
Pope County, Ark.:			
Atkins	do	290	1,036
Do	do	315	1,016
Pitt County, N. C.:			
Coupers	Jan. 4	319	925
Do	do	327	978
Do	do	329	931
Do	do	331	953
Do	do	336	925
Do	do	346	928
Cabarrus County, N. C.:			
Concord	Oct. 18	317	972
Do	do	319	959
Do	Oct. 19	327	956
Do	Oct. 20	331	972
Do	Oct. 21	321	937
Do	Oct. 22	315	963
Do	do	329	956
Do	do	352	1,032
Do	Oct. 24	319	1,013
Union County, N. C.:			
Monroe	Sept. 26	309	899
Do	do	354	861
Do	Sept. 27	327	896
Do	do	337	963
Do	Sept. 28	323	884
Do	Sept. 30	309	852
Do	do	347	1,007
Do	Nov. 12	349	915
Do	Nov. 14	329	909
Do	do	351	912
Do	Nov. 15	324	963
Do	do	347	947
Do	Nov. 16	328	940
Do	Nov. 17	354	931
Do	do	359	896
Do	Nov. 18	332	893
Do	Dec. 13	321	883
Do	do	331	883
Do	do	331	934
Do	do	360	865
Bamberg County, S. C.:			
Bamberg	Oct. 3	340	845
Do	do	352	874
Do	do	357	823
Do	do	361	861
Barnwell County, S. C.:			
Allendale	Sept. 18	347	934
Do	do	348	871
Do	do	359	918
Do	do	371	893
Greenwood County, S. C.:			
Greenwood	Nov. 5	300	1,036
Do	do	310	1,001
Do	do	316	906
Do	do	334	922
Do	do	336	972
Do	do	342	1,051
Do	do	363	941
Williamsburg County, S. C.:			
Gordons	Sept. 26	336	827
Do	do	355	868
Do	do	364	807
Do	do	371	899

TABLE VIII.—*Variation of yields of oil and meal on same market*—Continued.

Origin.	Date sold.	Oil.	Meal.	Origin.	Date sold.	Oil.	Meal.
Barnwell County, S. C.:	1915	*Pounds.*	*Pounds.*	Greenwood County, S. C.:	1915	*Pounds.*	*Pounds.*
Dunbarton	Jan. 16	322	922	Greenwood	Nov. 11	326	959
Do	...do	343	928	Do	...do	333	1,032
Do	...do	346	922	Do	...do	344	1,007
Do	...do	322	928	Do	...do	350	975
Do	...do	334	953	Do	...do	326	928
Do	...do	323	887	Do	Nov. 12	295	1,042
Do	...do	357	963	Do	...do	337	902
Florence County, S. C.:				Do	Nov. 15	313	1,070
Olanta	Dec. 5	348	918	Do	...do	331	1,086
Do	Dec. 6	311	972	Do	...do	315	921
Do	...do	315	944	Do	Nov. 16	317	982
Do	...do	335	956	Do	...do	317	980
Do	...do	337	979	Do	...do	342	1,048
Do	Dec. 9	324	918	Do	...do	354	947
Do	Dec. 10	340	921				

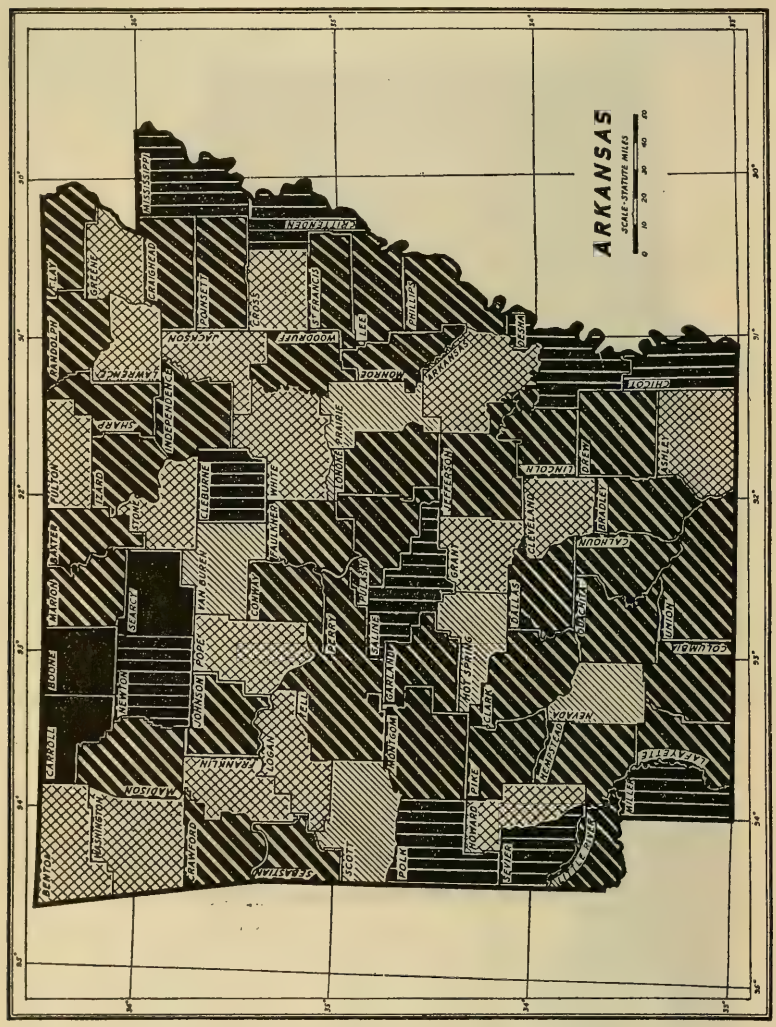
Bul. 948, U. S. Dept. of Agriculture. MAP I.

[See table on p. 8.]



Bul. 948, U. S. Dept. of Agriculture. MAP II.

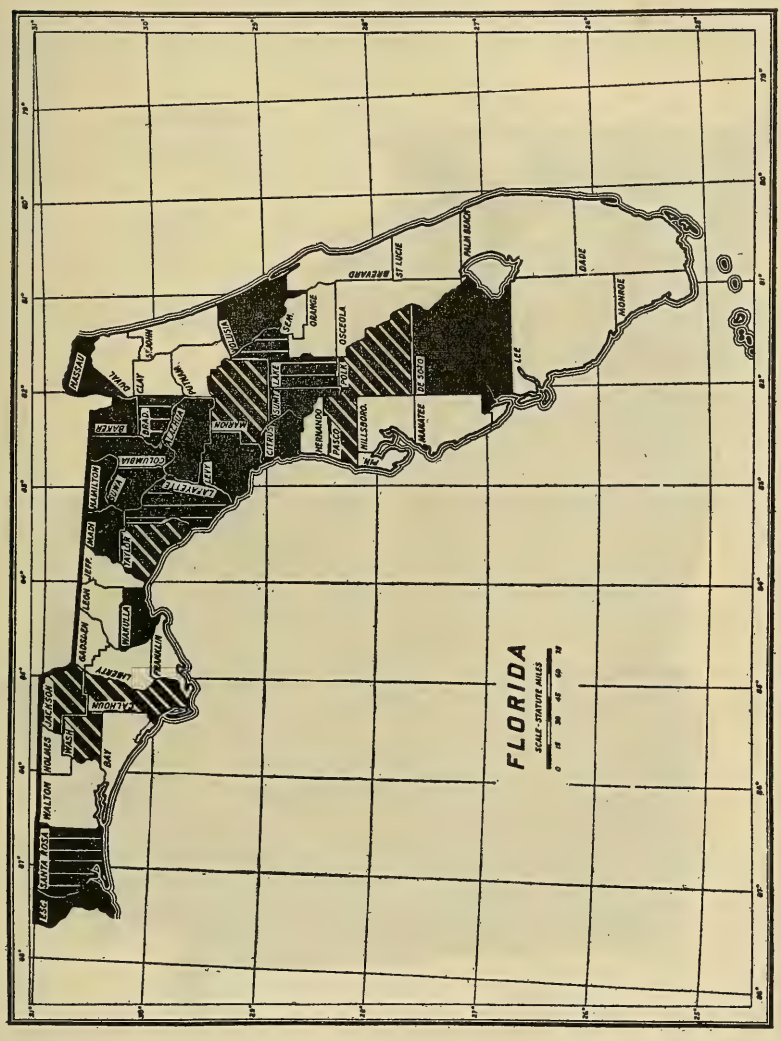
[See table on p. 24.]



For meaning of shading, see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. MAP III.

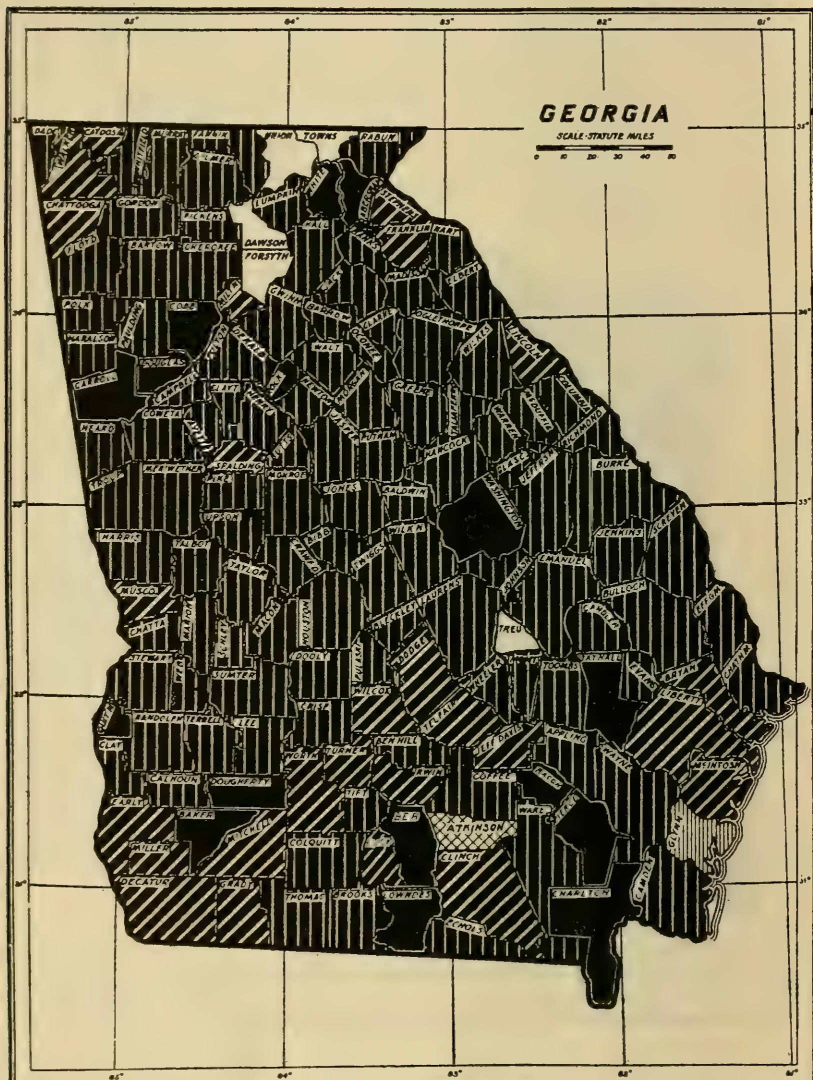
[See table on p. 42.]



For meaning of shading, see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. **MAP IV.**

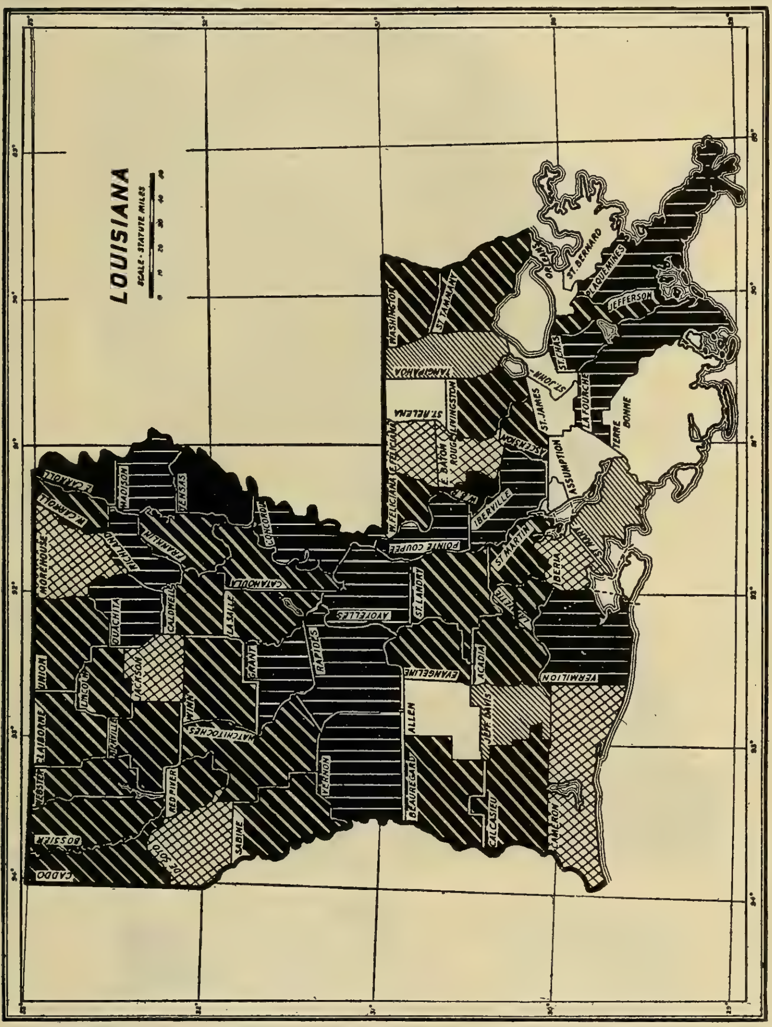
[See table on p. 49.]



For meaning of shading, see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. **MAP V.**

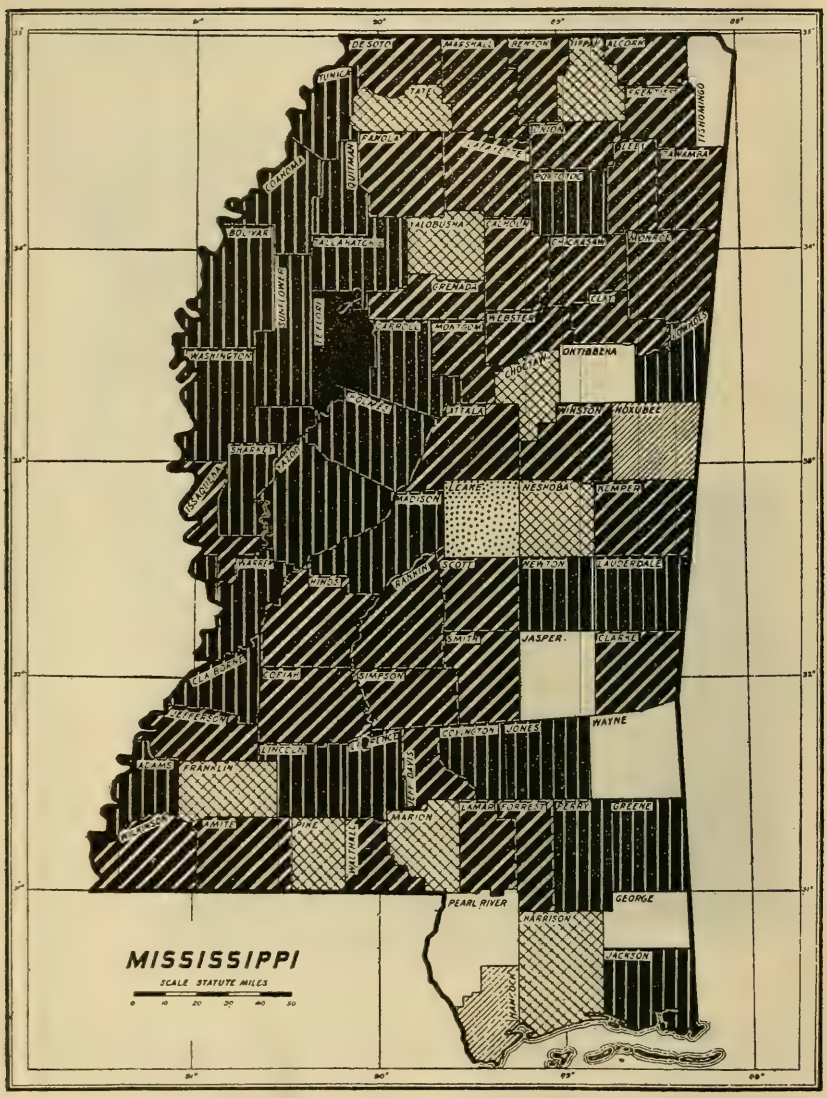
[See table on p. 85.]



For meaning of shading see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. **MAP VI.**

[See table on p. 97.]



For meaning of shading, see legend on Map I.

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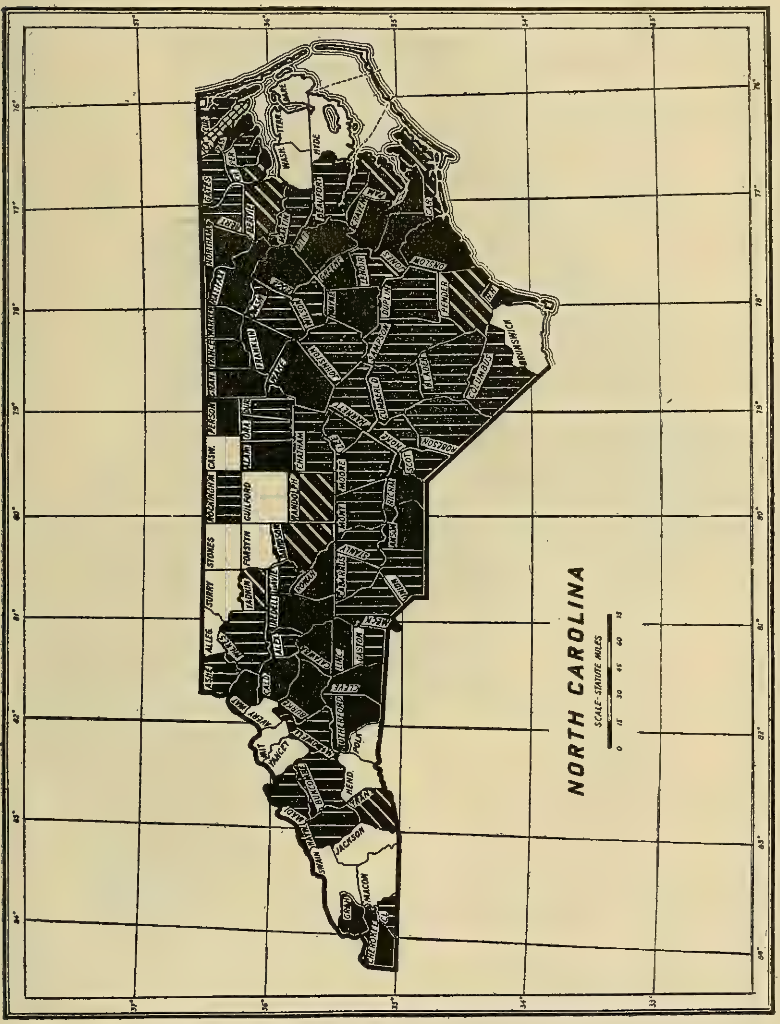
MAP VII.

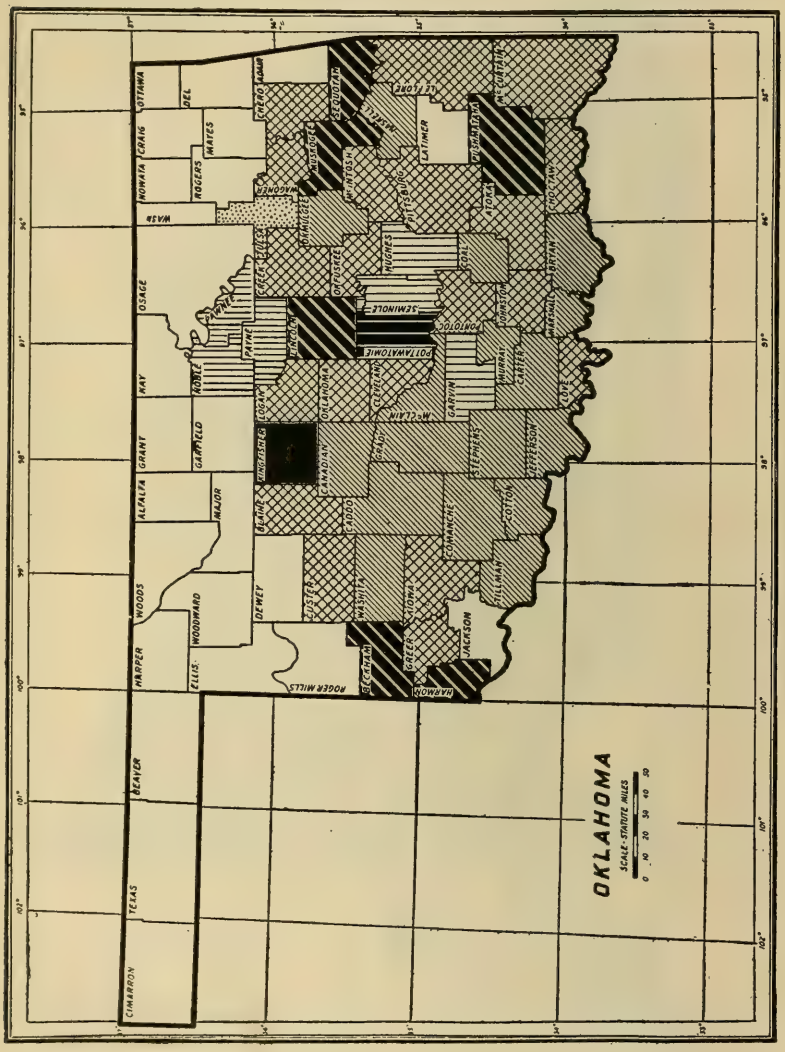
[See table on p. 117.



For meaning of shading, see legend on Map I.

Bul. 948, U. S, Dept. of Agriculture. **MAP VIII.**

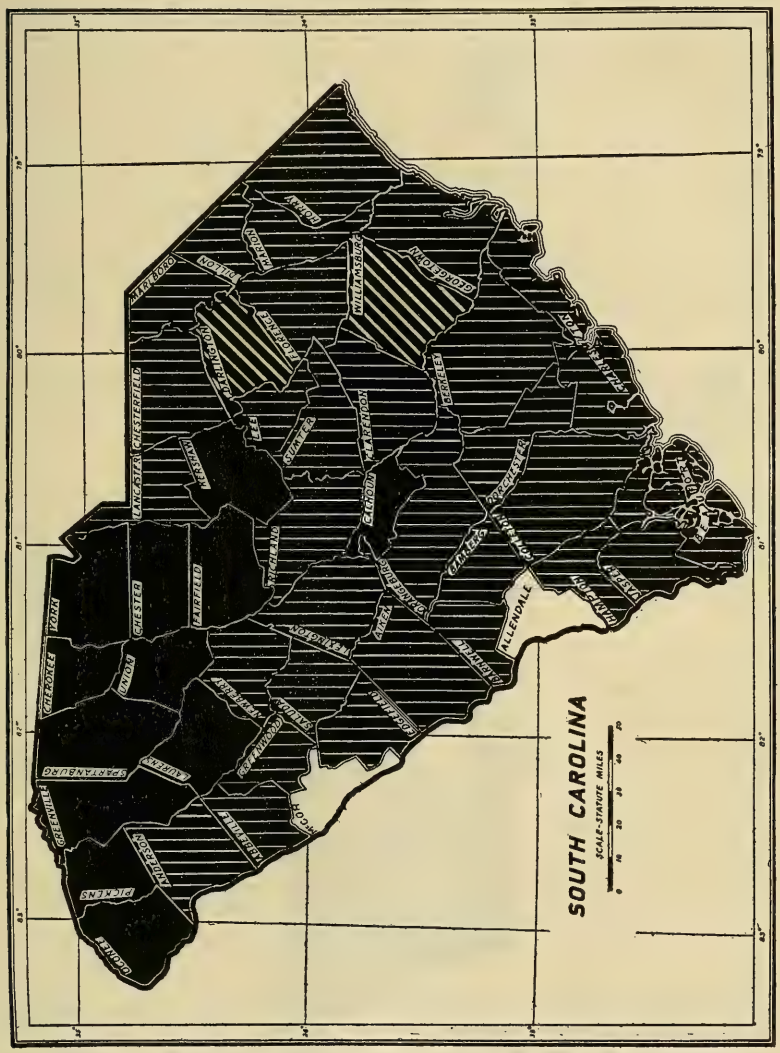
[See table on p. 134.]



For meaning of shading, see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. MAP IX.

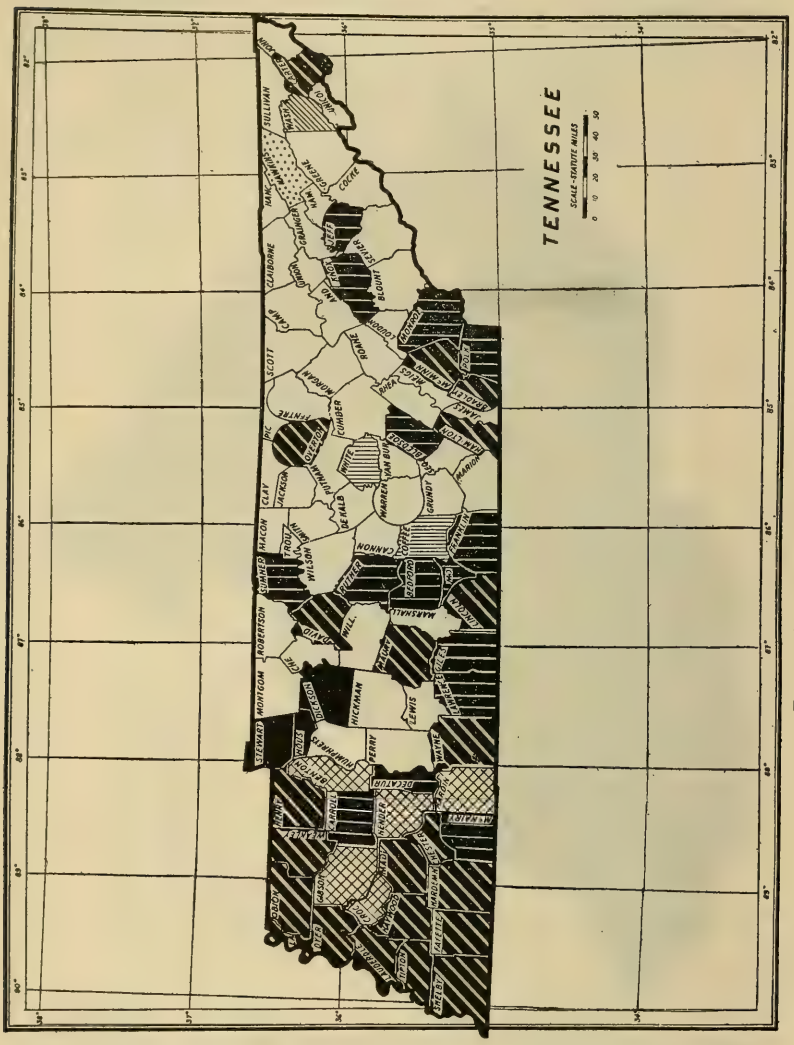
[See table on p. 146.]



For meaning of shading, see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. MAP X.

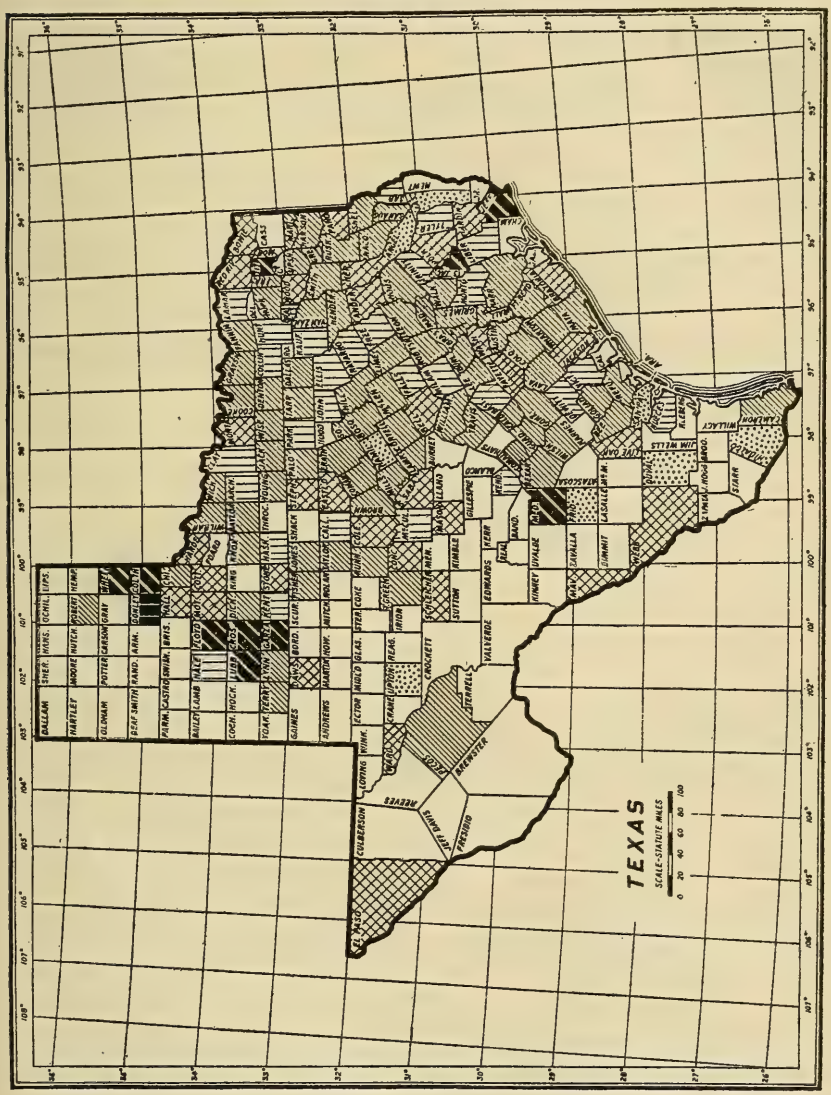
[See table on p. 157.]



For meaning of shading, see legend on Map I.

Bul. 948, U. S. Dept. of Agriculture. MAP XI.

[See table on p. 167.]



For meaning of shading, see legend on Map I.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 949

Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C. ▼ October 10, 1921

STANDARD AND TENTATIVE METHODS OF SAMPLING AND TESTING HIGHWAY MATERIALS.

Recommended by the Second Conference of State Highway Testing Engineers and Chemists, Washington, D. C., Feb. 23–27, 1920.

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INTRODUCTION.

In connection with the administration of Federal appropriations for highway construction, conferences have been held from time to time, between representatives of the Bureau of Public Roads and of the various State highway departments, for the purpose of formulating policies relative to matters of mutual interest. In accordance with this general plan, a conference of testing engineers of the State highway departments was deemed advisable in order to standardize the work of the State highway department laboratories and the bureau laboratories.

The conference held at the Bureau of Public Roads, Washington, was called by the committee on tests and investigations of the American Association of State Highway Officials and the following representatives of State highway departments and of the Bureau of Public Roads were in attendance, for all or a part of the conference:

Agg, T. R., Iowa.
Anderton, B. A., Bureau of Public Roads.
Begg, R. B. H., Virginia.
Bragg, J. G., New Jersey.
Carmick, L. G., Bureau of Public Roads.
Cooper, W. F., Louisiana.
Dayton, R. B., West Virginia.
Dean, A. W., Massachusetts.
Gage, R. B., New Jersey.
Goldbeck, A. T., Bureau of Public Roads.

Grimes, J. F., Kentucky.
Hinderlite, H. B., North Carolina.
Hutchinson, G. W., Delaware.
Jackson, F. H., Bureau of Public Roads.
Lang, F. C., Minnesota.
Leavitt, H. Walter, Maine.
Maddocks, Frederick T., California.
Martin, W. D., Ohio.
Milburn, Henry M., Bureau of Public Roads.
Purrington, W. F., New Hampshire.
Rea, A. S., Ohio.
Roman, F. L., Illinois.
Rossell, F. C., Maryland.
Saunders, R. L., Connecticut.
Seaton, R. A., Kansas.
Smith, E. B., Bureau of Public Roads.
Terrell, D. V., Kentucky.
Ulman, Malcolm H., Pennsylvania.
Withey, M. O., Wisconsin.

The important recommendations which resulted from the conference are due largely to the painstaking and effective work of the testing engineers who participated.

Standard methods of sampling and testing the materials employed in highway construction were adopted, as set forth in this bulletin. It will be noted that the standard methods adopted by the American Society for Testing Materials have been accepted so far as the field has been covered by that society. In some of the methods minor revisions of the A. S. T. M. standards have been made, and where that has been done, the notation that follows the title of the test or method indicates that there has been such revision.

For tests that have not been standardized by the American Society for Testing Materials, the methods of testing set forth in Bulletins 314, 347, and 555 of the U. S. Department of Agriculture, contributed by the Bureau of Public Roads, have been adopted for the most part. Several new tests and revisions of old tests are suggested for trial, to be adopted later if they prove to be satisfactory.

It will be noted that for the convenience of testing departments, there is given the full text of all tests usually employed in a highway department testing laboratory. This has been done because it is believed it will save time and avoid confusion to have all of this material available in a single volume.

The tests set forth in this bulletin are recommended as official standards by the committee on tests and investigations of the American Association of State Highway Officials, and this recommendation is concurred in by the Bureau of Public Roads.

The recommendations of the conference were assembled and arranged by T. R. Agg, chairman of the committee on tests and investigations of the American Association of State Highway Officials, and A. T. Goldbeck, engineer of tests of the Bureau of Public Roads.

TESTS FOR NON-BITUMINOUS ROAD MATERIALS.

1. ABRASION TEST FOR BROKEN STONE.

(A. S. T. M. Standard method, serial designation D 2–08, slightly modified.)

(1) The machine (see fig. 1) shall consist of one or more hollow iron cylinders, closed at one end and furnished with a tightly fitting iron cover at the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth inside. These cylinders are to be mounted on a shaft at an angle of 30° with the axis of rotation of the shaft.

(2) The rock to be tested shall be broken from large irregular pieces to as nearly uniform size as possible, and as near to 50 pieces as possible shall constitute a test sample. No pieces having edges or faces that have been rounded by wear shall be included. The total weight of rock in a test shall be within 10 grams of 5 kilograms. All test pieces shall be washed and thoroughly dried before weighing. Ten thousand revolutions, at the rate of between 30 and 33 per minute, shall constitute a test. Only the percentage of material worn off which will pass through a 0.16-cm. ($\frac{1}{16}$-inch) mesh sieve shall be considered in determining the amount of wear. This shall be expressed as the percentage of the 5 kilograms used in the test.

(3) For materials having a specific gravity below 2.20 the quantity used for the test shall be adjusted on a volume basis, retaining the specified number and size of pieces. For such materials a volume of 4,000 c. c. of the broken stone or broken slag shall be used.

2. ABRASION TEST FOR GRAVEL.

(1) The aggregate shall first be screened through screens having circular openings 2 inches, $1\frac{1}{2}$ inches, 1 inch, $\frac{3}{4}$ inch, and $\frac{1}{2}$ inch in diameter. The material of these sizes shall be washed and dried. The following weights of the dried stone shall then be taken: 1,250 grams of the size passing the 2-inch and retained on the $1\frac{1}{2}$-inch screen, 1,250 grams of the size passing the $1\frac{1}{2}$-inch and retained on the 1-inch screen, 1,250 grams passing the 1-inch screen and retained on the $\frac{3}{4}$-inch screen, 1,250 grams passing

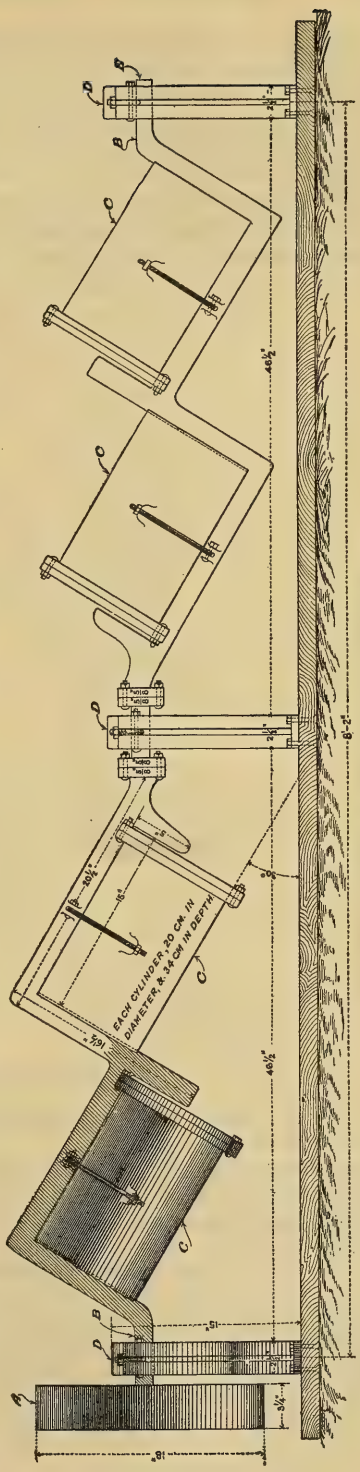


FIG. 1.—Abrasion machine—Deval type (front view).

the $\frac{3}{4}$-inch screen and retained on the $\frac{1}{2}$-inch screen. This material shall be placed in the cast-iron cylinder of the Deval machine as specified for the standard abrasion test on stone. Six cast-iron spheres 1.875 inches in diameter and weighing approximately 0.95 pound (0.45 kg.), each, shall be placed in the cylinder as an abrasive charge. These spheres are the same as those used in the standard rattler test for paving brick.

(2) The duration of the test and the rate of rotation shall be the same as specified for the standard test for stone, namely, 10,000 revolutions at a rate of 30 to 33 revolutions per minute. At the completion of the test the material shall be taken out and screened over a $\frac{1}{16}$-inch mesh sieve. The material retained upon the sieve shall be

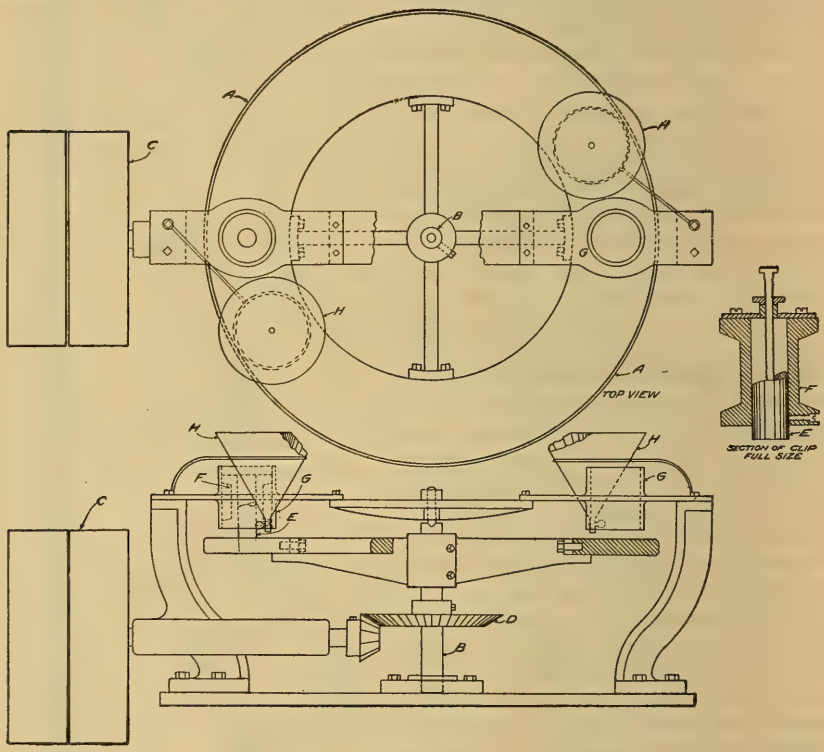


FIG. 2.—Details of Dorry hardness machine.

washed and dried and the percentage loss by abrasion of the material passing the $\frac{1}{16}$-inch mesh sieve calculated.

(3) When the material has a specific gravity below 2.20 a total weight of 4,000 grams made up of the four groups of sizes described above, instead of 5,000 grams, shall be used in the abrasion test.

3. DORRY HARDNESS TEST FOR ROCK.

(1) A core 25 mm. in diameter and about 10 cm. long shall be cut with the diamond drill from the specimen to be examined. The core should in every case be drilled perpendicular to the bedding plane of the rock. After thoroughly drying, the specimen shall be inserted in grip of the Dorry machine (fig. 2), leaving about 1 inch projecting from the lower end. The grip shall then be inserted in the sleeve so that the

lower end of the specimen rests on the steel disk. The funnel shall be filled with sand and the machine run until the lower end of the specimen has been worn down to the plane of the disk. The grip carrying the specimen shall then be removed, brushed free of dust, and accurately weighed. By means of small metal washers, any one or more of which may be slipped over the projecting rod of the grip, the initial weight shall be adjusted to exactly 1,250 grams. The grip shall then be replaced in the same position as before and the machine given 1,000 revolutions at the rate of 30 per minute, after which the grip and specimen shall be weighed again. The

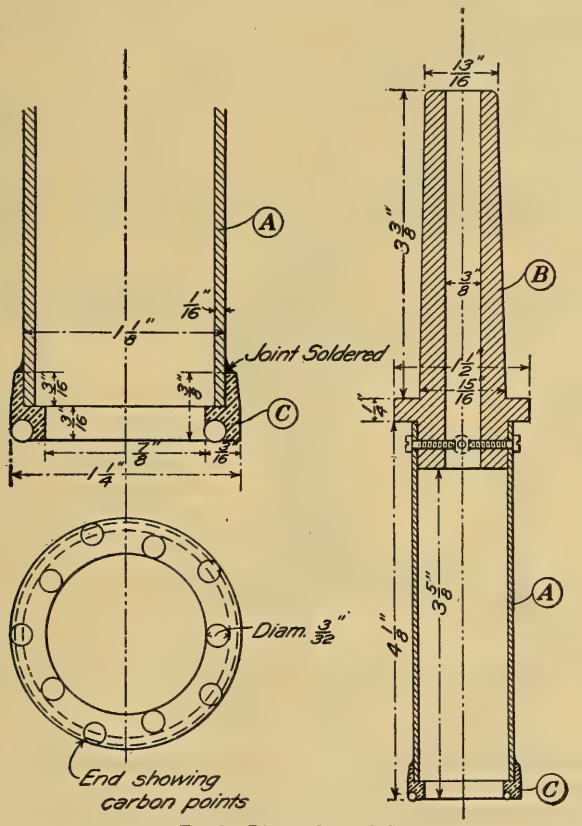


FIG. 3.—Diamond core drill.

test shall be repeated with the specimens reversed, in order to obtain the average hardness of the two ends.

(2) The sand used as the abrasive agent shall be a crushed quartz, screened to pass a standard sieve having 30 meshes per linear inch and to be retained on a standard sieve having 40 meshes per linear inch. Since it is almost impossible to obtain such a sand commercially, it is customary to specify a sand not more than 5 per cent of which will be retained on a No. 30 sieve and not more than 25 per cent of which will pass a No. 40 sieve. Sand known to the trade as No. 2½ quartz will usually fulfill these requirements. The ¼-inch opening in the funnel of the hardness machine will allow about 18 pounds of sand to pass through during a test.

(3) Calling the initial weight of grip plus specimen a, the final weight after 1,000 revolutions b,

$$\text{the coefficient of hardness} = 20 - \frac{(a-b)}{3}.$$

(4) The coefficient 20 is chosen as the standard of comparison to give about the same range of values as those obtained by the Deval abrasion test. The loss in weight is divided by 3 in order to avoid negative coefficients, since it is found that a specimen may lose as high as 60 grams in a single test.

4. TEST FOR TOUGHNESS OF ROCK.

(A. S. T. M. Standard Method, Serial Designation: D 3–18.)

(1) Toughness, as applied to rock, is the resistance offered to fracture by impact, expressed as the height of the final blow of a standard hammer required to cause fracture of a cylindrical test specimen of given dimensions.

(2) Quarry samples of rock from which test specimens are to be prepared shall measure at least 6 inches on a side and at least 4 inches in thickness, and when possible shall have the plane of structural weakness of the rock plainly marked thereon. Samples shall be taken from freshly quarried material, and only from pieces which show no evidences of incipient fracture due to blasting or other causes. The samples shall preferably be split from large pieces by the use of plugs and feathers and not by sledging. Commercial stone-block samples from which test specimens are to be prepared, shall measure at least 3 inches on each edge.

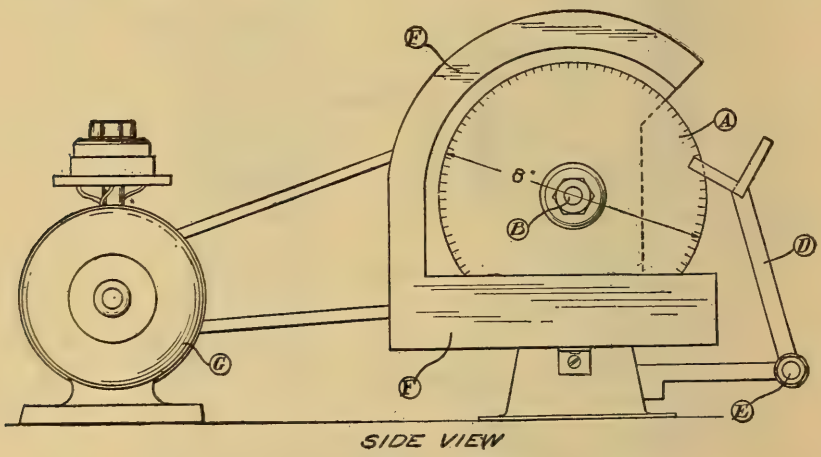


FIG. 4.—Details of diamond saw.

(3) Specimens for test shall be cylinders prepared as described in paragraph 4, 25 mm. in height and from 24 to 25 mm. in diameter. Three test specimens shall constitute a test set. The ends of the specimen shall be plane surfaces at right angles to the axis of the cylinder.

(4) One set of specimens shall be drilled perpendicular and another parallel to the plane of structural weakness of the rock, if such plane is apparent. If a plane of structural weakness is not apparent, one set of specimens shall be drilled at random. Specimens shall be drilled in a manner which will not subject the material to undue stresses and which will insure the specified dimensions. The ends of the cylinders may be sawed by means of a band or diamond saw,[1] or in any other way which will not induce incipient fracture, but shall not be chipped or broken off with a hammer. After sawing, the ends of the specimens shall be ground plane with water and carborundum or emery on a cast-iron lap (see fig. 5) until the cylinders are 25 mm. in length.

(5) Any form of impact machine which will comply with the following essentials may be used in making the test:

[1] Satisfactory forms of diamond drill and diamond saw are shown in figs. 3 and 4.

(*a*) A cast-iron anvil weighing not less than 50 kg., firmly fixed upon a solid foundation;

(*b*) A hammer weighing 2 kg., arranged so as to fall freely between suitable guides;

(*c*) A plunger made of hardened steel and weighing 1 kg., arranged to slide freely in a vertical direction in a sleeve, the lower end of the plunger being spherical in shape with a radius of 1 cm.;

(*d*) Means for raising the hammer and for dropping it upon the plunger from any specified height from 1 to not less than 75 cm., and means for determining the height of fall to approximately 1 mm.;

(*e*) Means for holding the cylindrical test specimen securely on the anvil without rigid lateral support and under the plunger in such a way that the center of its upper

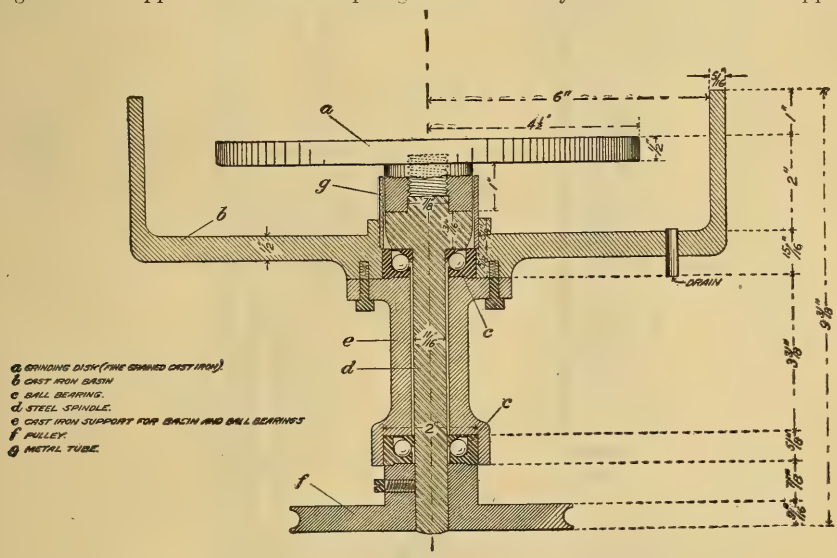


FIG. 5.—Details of grinding lap.

surface shall throughout the test be tangent to the spherical end of the plunger at its lowest point.

(6) The test shall consist of a 1 cm. fall of the hammer for the first blow, a 2 cm. fall for the second blow, and a fall increasing by 1 cm. for each succeeding blow until failure of the test specimen occurs.

(7) The height of the blow in centimeters at failure shall be the toughness of the test specimen. The individual and the average toughness of three test specimens shall be reported when no plane of structural weakness is apparent. In cases where a plane of structural weakness is apparent, the individual and average toughness of the three specimens in each set shall be reported and identified. Any peculiar condition of a test specimen which might affect the result, such as the presence of seams, fissures, etc., shall be noted and recorded with the test result.

5. TESTS FOR APPARENT SPECIFIC GRAVITY AND ABSORPTION OF STONE OR OTHER COARSE MATERIALS.

(1) The apparent specific gravity shall be obtained by weighing the water displaced by a sample of the material weighing approximately 1,000 grams, broken into pieces about $1\frac{1}{4}$ inches in diameter. The vessel to be used is shown in figure 7. It consists of a galvanized-iron cylinder closed at one end and measuring 5 inches in diameter by 8 inches high. A brass spout $\frac{1}{2}$ inch in diameter is soldered into

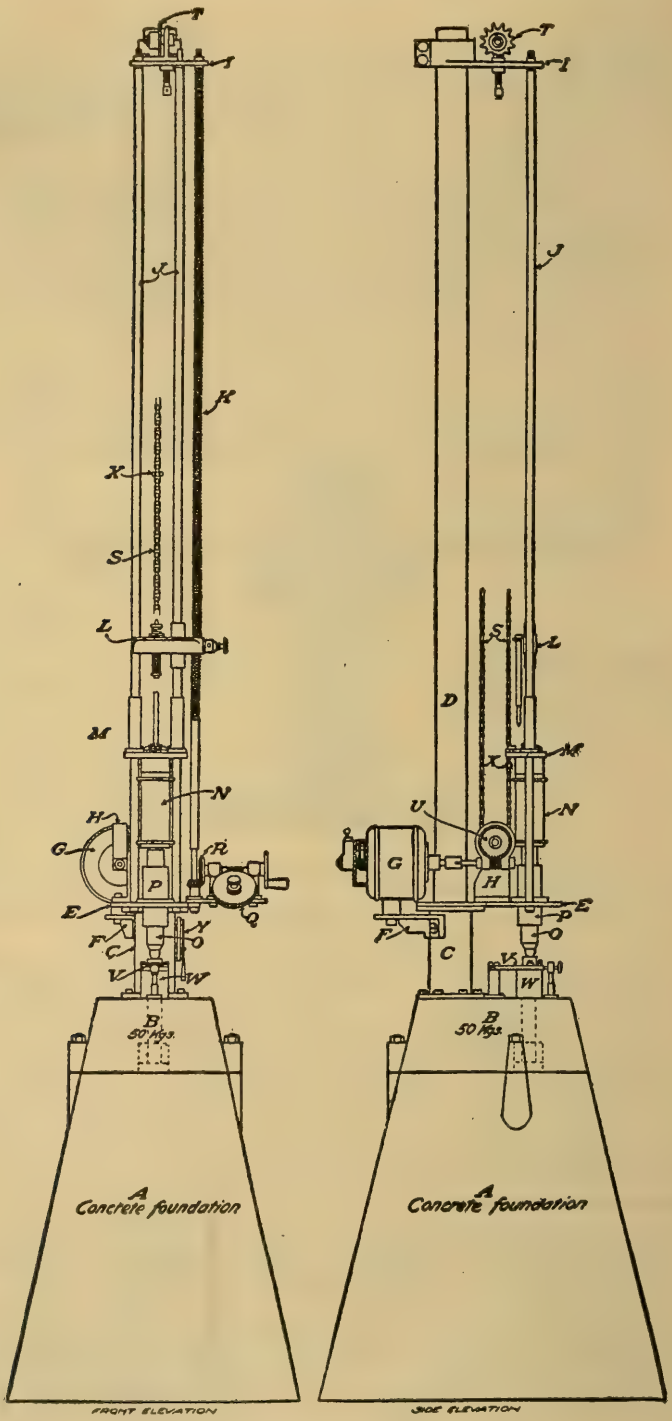


FIG. 6.—Details of Page impact testing machine.

the side of the cylinder 6 inches from the bottom. The spout is inclined at an angle of 2° with the horizontal and is 2½ inches long. A notch is filed across its lower end, as shown, to stop the drip from the displaced water. To determine the specific gravity, the dried and cooled sample shall be weighed to the nearest 0.5 gram and immersed in water for 24 hours. The pieces shall then be surface-dried individually with a towel, the sample reweighed and immediately placed in the cylinder, which has been previously filled to overflowing with water at room temperature.

(2) The weight of water displaced by the sample shall be used to calculate its apparent specific gravity. The difference between the original weight of the sample and its weight after 24 hours shall be used to determine the absorption.

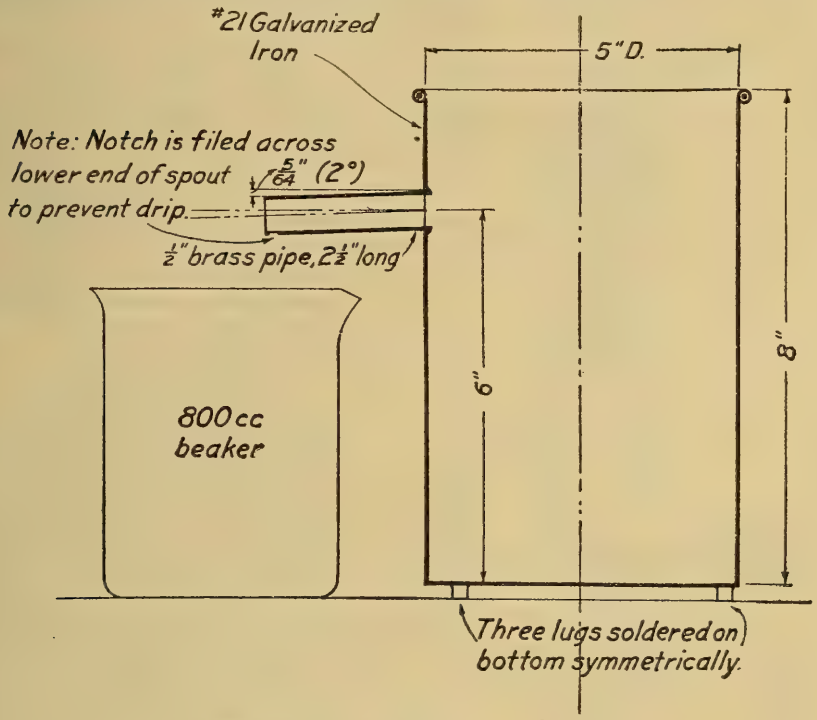


FIG. 7.—Vessel used in making specific-gravity and absorption tests.

6. TESTS FOR APPARENT SPECIFIC GRAVITY OF SAND, STONE, OR SLAG SCREENINGS AND OTHER FINE NON-BITUMINOUS HIGHWAY MATERIALS.

(A. S. T. M. Standard Methods, Serial Designation: D 55-19.)

(1) The following tests, "Le Chatelier" and "Jackson," are equally suited for use in determining the apparent specific gravity of sand, stone, and slag screenings and other fine non-bituminous highway materials and may be considered as alternates.

I. LE CHATELIER TEST.

(2) The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in figure 8. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

(3) (*a*) The flask shall be filled with either of the liquids to a point on the stem between zero and 1 c. c., and 64 grams of sand or other fine non-bituminous highway material of the same temperature as the liquid shall be slowly introduced, taking care that the material does not adhere to the inside of the flask above the liquid and to free the material from air by rolling the flask in an inclined position. After all material is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 grams of the material.

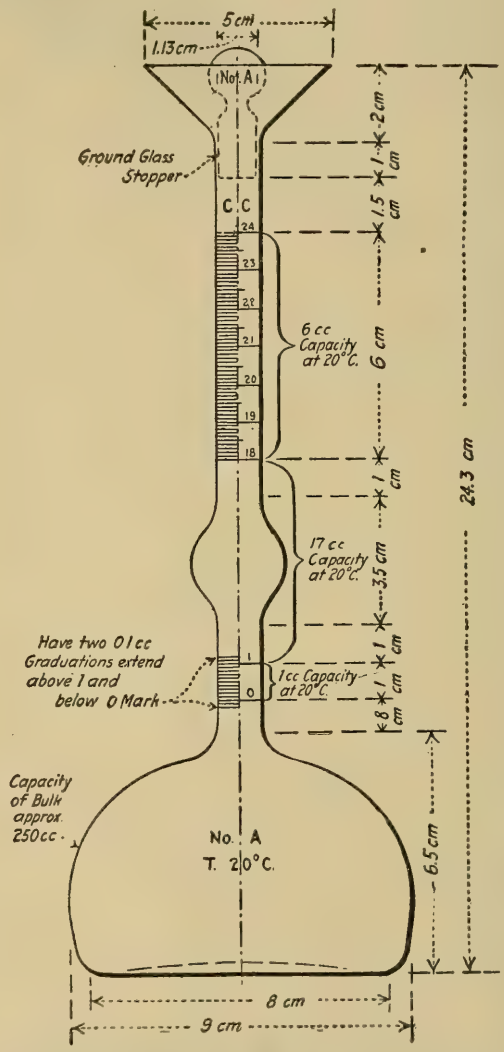


FIG. 8.—Le Chatelier apparatus for specific-gravity determinations.

The specific gravity shall then be obtained from the formula

$$\text{Sp. grav.} = \frac{\text{Weight of material (g)}}{\text{Displaced volume (c. c.)}}$$

(*b*) The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5° C. The results of repeated tests should agree with 0.01.

II. JACKSON TEST.

(4) The determination shall be made with a Jackson specific-gravity apparatus (illustrated in fig. 9), which shall consist of a burette, with graduations reading to 0.01 in specific gravity, about 23 cm. (9 inches) long and with an inside diameter of about 0.6 cm. (0.25 inch), which shall be connected with a glass bulb approximately 13 cm. (5.5 inches) long and 4.5 cm. (1.75 inches) in diameter, the glass bulb being of such size that from a mark on the neck at the top to a mark on the burette just below the bulb, the capacity is exactly 180 c. c. (6.09 liquid ounces); and an Erlenmeyer flask, which shall contain a hollow ground-glass stopper having the neck of the same bore as the burette, and shall have a capacity of exactly 200 c. c. (6.76 ounces) up to the graduation on the neck of the stopper.

(5) The method is as follows: (1) Dry at not more than 110° C. (230° F.) to a constant weight a sample weighing about 55 grams; (2) weigh 50 grams of the dry sample to 0.1 gram and pour it into the unstoppered Erlenmeyer flask, which shall be cleaned and dried before each determination; (3) fill the bulb and burette with kerosene, leaving just space enough to take the temperature by introducing a thermometer

through the neck; (4) remove the thermometer and add sufficient kerosene to fill exactly to the mark on the neck, drawing off any excess with the burette; (5) run into the flask about one-half of the kerosene in the bulb to remove air bubbles and then run in more kerosene, removing any material adhering to the neck of the flask, until the kerosene is just below the ground glass; (6) place the hollow ground-glass stopper in position and turn it to fit tightly and then run in kerosene exactly to the 200 c. c. (6.76 ounces) graduation on the neck, care being taken to remove all air bubbles in the flask; (7) read the specific gravity from the graduation on the burette, and the temperature of the oil in the flask, noting the difference between the temperature of the oil in the bulb before the determination and that of the oil in the flask after the determination; (8) make a temperature correction to the reading of the specific gravity in accordance with the table furnished by the manufacturer of the apparatus, adding the correction if the temperature of the kerosene has increased and subtracting it if the temperature of the kerosene has decreased.

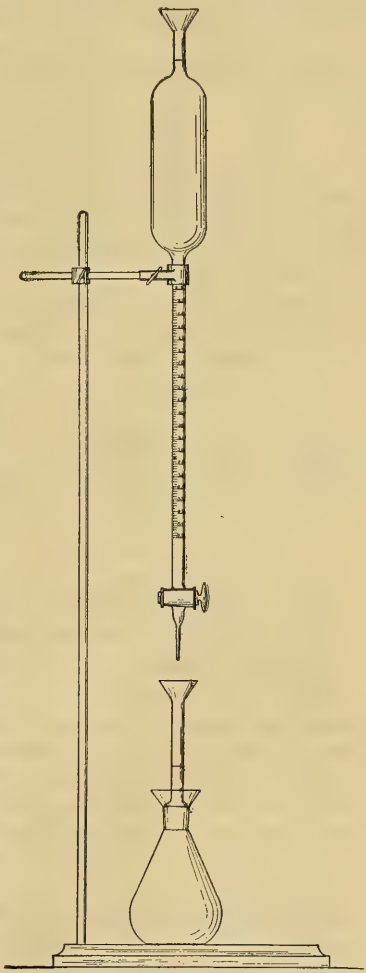


FIG. 9.—Jackson specific-gravity apparatus.

7. WEIGHT PER CUBIC FOOT AND VOID TESTS ON COARSE AGGREGATE.

(1) The weight per cubic foot of coarse aggregate shall be determined as follows: A cylindrical measure of at least one-fourth cubic foot capacity, with inside diameter approximately equal to inside height, or a box approximately cubical in shape and of not less than one-half cubic foot capacity shall be used. Ordinarily, the determination should be made on aggregate in air-dry condition. When the aggregate contains an appreciable amount of moisture, the percentage of water by weight shall be determined and recorded.

(2) About one-fourth of the total amount of aggregate necessary to fill the measure shall first be introduced in such manner as to avoid separation of sizes. This material shall then be shaken down by rocking the measure from side to side until no further settlement takes place. The process shall be repeated until the measure has been filled to overflowing, after which it shall be struck off level with the top with a straightedge and weighed.

The percentage of voids in the aggregate may be determined from the weight per cubic foot and specific gravity in the usual manner.

8. WEIGHT PER CUBIC FOOT TEST FOR FINE AGGREGATE.

(1) For determining weight per cubic foot of fine aggregate use a cylindrical metal measure having an inside diameter equal to the inside depth. A measure of capacity of one-fifth to one-half cubic foot is suggested, but a measure as small as one-twentieth cubic foot capacity may be used. Ordinarily the weight per cubic foot should be

determined on air-dry material. When the aggregate contains an appreciable amount of moisture the percentage of water by weight shall be determined and recorded.

(2) Fill the measure one-third full, puddle with 25 to 30 strokes from a ½-inch round steel bar 20 inches long, pointed at the lower end. Continue filling and puddling in like manner until the measure is full, then strike off the top by a rolling motion with the bar. Determine the weight of the contents of the measure and calculate the weight in pounds per cubic foot.

9. SIEVE ANALYSIS OF BROKEN STONE, GRAVEL, PEBBLES OR BROKEN SLAG.

(A. S. T. M. Standard Method, D 18–16, slightly modified.)

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing in pounds six times the diameter in inches of the largest holes required; (2) passing the sample through such of the following size screens having circular openings as are required or called for by the specifications, screens to be used in the order named: 8.89 cm. (3½ inches), 7.62 cm. (3 inches), 6.35 cm. (2½ inches), 5.08 cm. (2 inches), 3.81 cm. (1½ inches), 3.18 cm. (1¼ inches), 2.54 cm. (1 inch), 1.90 cm. (¾ inch), 1.27 cm. (½ inch), and 0.64 cm. (¼ inch); (3) determining the percentage by weight retained on each screen; and recording the mechanical analysis in the following manner:

	Per cent.
Passing 0.64 cm. (¼ inch) screen	.....
Passing 1.27 cm. (½ inch) screen and retained on a 0.64 cm. (¼ inch) screen	.....
Passing 1.90 cm. (¾ inch) screen and retained on a 1.27 cm. (½ inch) screen	.....
Passing 2.54 cm. (1 inch) screen and retained on a 1.90 cm. (¾ inch) screen	.....
.....	.....
	100.00

10. SIEVE ANALYSIS OF SAND OR FINE AGGREGATE.

(A. S. T. M. Standard, Serial Designation: D 7–18, slightly modified.)

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing not less than 100 grams and not more than 500 grams; (2) passing the sample through each of the mesh sieves [2] (American Society for Testing Materials standard sieves) specified in Table 1; (3) determining the percentage by weight retained on each sieve, the sifting being continued on each sieve until less than 1 per cent of the weight retained on each sieve shall pass through the sieve during the last minute of sifting; and (4) recording the mechanical analysis in the following manner:

	Per cent.
Passing 200-mesh sieve	.....
Passing 100-mesh sieve and retained on a 200-mesh sieve	.....
Passing 80-mesh sieve and retained on a 100-mesh sieve	.....
Passing 50-mesh sieve and retained on an 80-mesh sieve	.....
.....	.....
	100.00

[2] The order in which the sieves are to be used in the process of sifting is immaterial and shall be left optional; but in reporting results the order in which the sieves have been used shall be stated.

TABLE I.—*A. S. T. M. standard sieves.*

Mesh designation.	Unit of measure.	Actual mesh.	Opening.	Wire diameter.	Permissible variations.	
					Mesh.	Diameter.
10[1]	Centimeter	3.9	0.200	0.056	0.04	0.005
	Inches	9.9	.079	.022	.1	.002
20	Centimeter	8	.085	.040	.2	.0015
	Inches	20.3	.0335	.0157	.5	.0006
30	Centimeter	12.0	.050	.033	.4	.0012
	Inches	30.5	.0197	.0130	1.0	.0005
40[1]	Centimeter	16	.036	.026	.6	.0010
	Inches	40.6	.0142	.0102	1.5	.0004
50	Centimeter	20	.029	.021	.8	.0010
	Inches	50.8	.0114	.0083	2	.0004
80[1]	Centimeter	31	.017	.015	1	.0008
	Inches	78.7	.0067	.0059	3	.0003
100[1]	Centimeter	39	.014	.0116	1	.0008
	Inches	99.1	.0055	.0046	3	.0003
200[1]	Centimeter	79	.0074	.0053	3	.0005
	Inches	200.7	.0029	.0021	8	.0002

[1] The ¼-inch circular opening screen and these sieves are recommended for the sieve analysis except for fine aggregate used in bituminous surfaces.

11. SIEVE ANALYSIS OF MIXTURES OF FINE AND COARSE AGGREGATES.

(A. S. T. M. Standard Method, Serial Designation: D 19-16, slightly modified.)

The method shall consist of (1) drying at not over 110°C. (230° F.) to a constant weight a sample weighing in pounds six times the diameter in inches of the largest holes required; (2) separating the sample by the use of a screen having circular openings 0.64 cm. (¼ inch) in diameter; (3) examining the portion retained on the screen in accordance with the standard method for making a sieve analysis of broken stone, gravel, pebbles, or broken slag (test No. 9), examining the portion passing this screen in accordance with the standard method for making a mechanical analysis of sand or other fine aggregate (test No 10); (4) and recording the mechanical analysis in the following manner:

	Per cent.
Passing 200-mesh sieve	.....
Passing 100-mesh sieve and retained on a 200-mesh sieve	.....
Passing 80-mesh sieve and retained on a 100-mesh sieve	.....
.....	.....
Passing 10-mesh sieve and retained on a 20-mesh sieve	.....
Passing 0.64-cm. (¼-inch) screen and retained on a 10-mesh sieve	.....
Passing 1.27-cm. (½-inch) screen and retained on a 0.64-cm. (¼-inch) screen	.....
Passing 1.90-cm. (¾-inch) screen and retained on a 1.27-cm. (½-inch) screen	.....
.....	.....
	100

In the sieve analysis of the sand fraction, the following sizes of sieves shall be used except for fine aggregate used for bituminous surfaces: ¼-inch circular opening, 10-mesh, 40-mesh, 80-mesh, 100-mesh, and 200-mesh.

12. TESTS FOR DETERMINING THE AMOUNT OF CLAY AND SILT IN SAND OR FINE AGGREGATE, IN GRAVEL AND IN SAND-CLAY, TOP SOIL, OR SEMIGRAVEL.

A. SAND OR FINE AGGREGATE.

(1) The specification covers the determination of the quantity of clay and silt in natural sand to be used in road construction.

(2) The sample as received shall be moistened and thoroughly mixed, then dried to constant weight at a temperature between 100° C. (212° F.) and 110° C. (230° F.).

(3) Five hundred (500) grams representative of the dried sample shall be placed in a dried and accurately weighed pan or vessel having vertical sides and provided with a pouring lip. This pan shall be substantially 22.9 cm. (9 inches) in diameter by not less than 10.2 cm. (4 inches) deep. Pour sufficient water in the pan to cover the sand (about 225 c. c.). Agitate vigorously for fifteen (15) seconds. Allow to settle for fifteen (15) seconds and then pour off the water into a tared evaporating dish, taking care not to pour off any sand. Repeat until the wash water is clear, using a glass rod to stir the material for the last few washings.

(4) Thoroughly dry the pan and washed sand in an oven at between 100° C. (212° F.) and 110° C. (230° F.), weigh and determine net weight of sand.

(5) Compute the per cent of clay and silt as follows:

$$\frac{\text{Original weight} - \text{weight after washing}}{\text{Original weight}} \times 100 = \text{per cent of clay and silt.}$$

For a check on the results, evaporate the wash water to dryness and weigh the residue.

$$\frac{\text{Weight of residue}}{\text{Original weight}} \times 100 = \text{per cent of clay and silt.}$$

B. GRAVEL.

(6) The specification covers the determination of the quantity of clay and silt in natural gravel to be used in road construction.

(7) The sample as received shall be moistened and thoroughly mixed, then dried to constant weight at a temperature between 100° C. (212° F.) and 110° C. (230° F.).

(8) A representative portion of the dry material, weighing not less than 50 times the weight of the largest stone in the sample, shall be selected from the sample, and placed in a dried and accurately weighed pan or vessel. The pan shall be 30.2 cm. (12 inches) in diameter by not less than 10.2 cm. (4 inches) deep, as nearly as may be obtained. Pour sufficient water in the pan to cover the gravel and agitate vigorously for fifteen (15) seconds, using a trowel or stirring rod. Allow to settle for fifteen (15) seconds, and then pour off the water into a tared evaporating dish, being careful not to pour off any sand. Repeat until the wash water is clear.

(9) Dry the washed material to constant weight in an oven at between 100° C. (212° F.) and 110° C. (230° F.), weigh, and determine net weight of gravel.

(10) Compute the per cent of clay and silt as follows:

$$\frac{\text{Original weight} - \text{weight after washing}}{\text{Original weight}} \times 100 = \text{per cent of clay and silt.}$$

C. SAND-CLAY, TOP SOIL, AND SEMIGRAVEL.

(11) Dry 500 grams of the material at a temperature below 350° F. (176.6° C.) to a constant weight. Gently pulverize to break down soft clods or masses, but not to grind or break hard material. Pass through a 10-mesh sieve, weigh the coarse residue, and record as "coarse material." Use the material passing the 10-mesh sieve as the starting point of a percentage analysis as follows:

(12) Weigh out two samples of 50 grams of this material for duplicate analysis. Place each in a tared wide-mouth bottle (5 to 6 cm. diameter and about 12 to 15 cm.

high). Add about 5 c. c. of dilute ammonia water and about 200 c. c. of water. Close with a cork or glass stopper and shake thoroughly for 20 minutes. Allow the sample to settle eight minutes and decant carefully or siphon off the supernatant liquid to a depth of 8 cm. below the surface of the liquid. (The depth of the liquid in the bottle should be sufficient to leave about 4 cm. below the point of siphoning.) Fill the bottle again with water, shake for three minutes, allow settlement, and siphon off as before. Repeat the process until the supernatant liquid is clear. Be careful to wash the stopper and neck of the bottle free from coarse material before decanting.

(13) Dry the bottle and washed material to constant weight at between 100° C. (212° F.) and 110° C. (230° F.), weigh and determine the net weight of washed material.

$$\frac{\text{Original weight} - \text{washed weight}}{\text{Original weight}} \times 100 = \text{per cent clay and silt.}$$

(14) As a check the washings drawn off shall be collected and evaporated to dryness for direct recovery of the fine sediment classed as clay and silt.

$$\frac{\text{Weight of residue}}{\text{Original weight}} \times 100 = \text{per cent clay.}$$

The determinations on the two samples shall check within 1 per cent to be acceptable.

13. TESTS FOR SEMIGRAVEL, TOP SOIL, AND SAND-CLAY.

The amount of clay and silt is first determined in accordance with test No. 12, then proceed as follows:

(1) Wash the contents of the bottle cleanly into a porcelain evaporating dish and carry to dryness on a water bath. The dried residue shall be carefully scraped from the dish and passed through a nest of 20, 60, 100, and 200 mesh sieves. The residue retained on each sieve shall be weighed and recorded as sand of the respective sizes. Their sum constitutes the total "sand." The residue passing the 200-mesh sieve and caught in the pan shall be weighed and recorded as "silt." Duplicate samples should check within 1 per cent.

(2) The coarse material shall be examined for hardness and with the magnifying glass to identify its character as quartz, hard iron compounds, feldspar, schistose material, or indurated clay. Hard quartz or iron gravels are valuable in themselves and as indicating the quality of the finer aggregate. Feldspar, mica, and clay nodules are worthless and indicate that the accompanying soil is poor for road building.

(3) The sands shall be examined with the magnifying glass for identification as quartz and for the presence of mica scales or feldspar needles. If mica or feldspar is present in appreciable amounts the sample should be rejected.

(4) When the clay is recovered by evaporation it can be examined for tenacity by cementing together two glass plates, each 1 inch wide, set at right angles, with a layer of clay whose thickness is fixed by a fine bent wire laid between the plates. The moist clay shall cover the wire on one plate, and the other plate shall be squeezed down tightly on the wire. After drying, the one plate shall be held firmly against cleats, wire slings shall be run symmetrically from the ends of the upper plate to one arm of a beam balance, and the tension necessary to separate the plates shall be given by shot or weights in the other pan of the balance. This test is tedious, and is of service chiefly on low-grade samples which are of doubtful efficiency, but which represent the only available material for local construction.

(5) Approximate tests for tenacity of mixture can be made as follows:

Make cylinders 25 mm. in height and 25 mm. in diameter from the material passing the 10-mesh sieve. Work the material into a stiff mud and mold under 132 kg. per square centimeter pressure. Dry thoroughly at 100° C. (212° F.) and break by the small Page impact machine for testing cementing value, using a 1-kg. hammer and 1-cm. drop. Record the number of strokes as the relative measure of tenacity.

Mix 50 grams of the material passing the 10-mesh sieve with —[3] grams of water and knead with the hands into a spherical ball. Measure the diameter. Let this ball drop from a height of —[3] cm. on a flat slab. Measure and record the reduction in diameter and examine the surface for cracks.

Usually the plastic character and adhesiveness of a good road soil can be judged by the feeling of the mud made from the material, its adherence to the hands and its stretch under light pulling.

14. TESTS FOR QUALITY OF WATER TO BE USED IN CONCRETE.

(1) *Acidity and alkalinity.*—The acidity and alkalinity test shall be made by immersing strips of blue and red litmus paper in a vessel of the water for a period of five minutes and noting color. A marked reversal in color indicates excessive acidity or alkalinity and the necessity for further tests.

(2) *Total solids and inorganic matter.*—Five hundred (500) cubic centimeters of the water shall be evaporated to dryness in a weighed dish. For this purpose a platinum dish of 100 to 200 c. c. capacity is found most convenient. The dish shall be nearly filled with the water and placed on a water bath, additional portions of the sample of water being added from time to time until 500 c. c. have been used. The contents of the dish shall be evaporated to dryness and the dish and contents cooled in a dessicator and weighed. The weight of the residue in grams divided by 5 is the per cent of total solids in the water.

(3) The total solids obtained as described, may consist of organic matter, of inorganic matter, or of combinations of organic and inorganic matter. The platinum dish shall be ignited at low red heat, and the darkening of the residue during the early stage of the ignition usually indicates the presence of organic matter. The per cent loss on ignition at low red heat will usually be an indication of the amount of organic matter, but it should be noted that some mineral salts tend to volatilize or partly decompose on heating.

(4) The determination of the decomposition of the mineral matter in the water usually requires a complete chemical analysis of the total solids obtained by the evaporation of 500 c. c., or more, of the water, and is not generally undertaken except when the percentage of total solids is large, or the water appears to give abnormal tests in other respects.

(5) A comparison of the given water with a water of known satisfactory quality can be obtained by making standard soundness, time of setting, and 1:3 mortar strength tests with standard sand, using the same cement of standard quality with each water. (Suggested limits for the last-named test are as follows: Any indication of unsoundness, marked change in time of setting, or a variation of more than 10 per cent in strength from results obtained with mixtures containing the water of satisfactory quality, shall be sufficient cause for rejection of the water under test.)

15. TEST FOR ORGANIC IMPURITIES IN CONCRETE AGGREGATES.

The test recommended is described in the "Proceedings of the American Society for Testing Materials, Philadelphia, Pa., Volume XIX, part 1, 1919, Appendix to Report of Committee C–9 on Concrete and Concrete Aggregates."

(1) The test as usually made consists of shaking the sand thoroughly in a dilute solution of sodium hydroxide (NaOH) and observing the resultant color after the mixture has been allowed to stand for a few hours. Fill a 12-oz. graduated prescription bottle to the 4½-oz. mark with the sand to be tested. Add a 3 per cent solution of sodium hydroxide until the volume of the sand and solution, after shaking, amounts to 7 ounces. Shake thoroughly and let stand for 24 hours. Observe the color of the clear

[3] No definite weight of water or height of fall recommended.

liquid above the sand. A good idea of the quality of the sand can be formed earlier than 24 hours, although this period is believed to give best results.

(2) If the solution resulting from this treatment is colorless, or has a light yellowish color, the sand may be considered satisfactory in so far as organic impurities are concerned. On the other hand, if a dark-colored solution of a color deeper than that indicted is produced, the sand should not be used in high-grade concrete such as that required in roads and pavements, or in building construction.

* * * * * * *

(3) Color values: While it is not practicable to give exact values for the reduction in strength corresponding to the different colors of solution, the tests made thus far show this relation to be about as follows:

Color No.[1]	Reduction in compressive strength of 1 : 3 mortar at 7 and 28 days.
	Per cent.
Figure 1	None.
Figure 2	10 to 20.
Figure 3	15 to 30.
Figure 4	25 to 50.
Figure 5	50 to 100.

[1] See Plate V, Proceedings of the American Society for Testing Materials, vol. xix, part 1, Report of Committee C-9, for Color Scale.

(4) Washing dirty sands has the effect of greatly reducing the quantity of organic impurities. However, even after washing, sands should be examined in order to determine whether the organic impurities have been reduced to harmless proportions.

The following list includes sufficient apparatus for making five field tests at a time: Five 12-oz. graduated prescription bottles; Stock of 3 per cent solution of sodium hydroxide (dissolve 1 oz. of sodium hydroxide in enough water to make 32 oz.)

This test does not give satisfactory results when lignite is present in the sand.

16. TEST FOR MORTAR MAKING QUALITY OF FINE AGGREGATES.

(1) When the fine aggregate is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1 : 3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a strength in tension and compression of at least ——[4] per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

(2) Preliminary acceptance samples shall be subjected to both 7 and 28 day tests and acceptance based thereupon. Samples tested during the progress of the work shall be accepted on the basis of the 7-day test.

17. STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT.

(A. S. T. M. Standard Method, Serial Designation: C 9–17.)

SPECIFICATIONS.

(1) Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

[4] It is recommended that the strength ratio be 100 per cent for this purpose.

CHEMICAL PROPERTIES.

(2) The following limits shall not be exceeded:

	Per cent.
Loss on ignition	4.00
Insoluble residue	.85
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	5.00

PHYSICAL PROPERTIES.

(3) The specific gravity of cement shall not be less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

(4) The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

(5) A pat of neat cement shall remain firm and hard and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

(6) The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

(7) The average tensile strength, in pounds per square inch, of not less than three standard mortar briquettes (see par. 51) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test.	Storage of briquettes.	Tensile strength per square inch.
Days.		*Pounds.*
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

(8) The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

PACKAGES, MARKING, AND STORAGE.

(9) The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

(10) The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment and in a suitable weather-tight building which will protect the cement from dampness.

INSPECTION.

(11) Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

REJECTION.

(12) The cement may be rejected if it fails to meet any of the requirements of these specifications.

(13) Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

(14) Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

(15) Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment as shown by weighing 50 packages taken at random is less than that specified, the entire shipment may be rejected.

TESTS.

Sampling.

(16) Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 pounds.

(17) (*a*) If sampled in cars one test sample shall be taken from each 50 barrels or fraction thereof. If sampled in bins one sample shall be taken from each 100 barrels.

(*b*) If sampled in cars one sample shall be taken from one sack in each 40 sacks (or 1 barrel in each 10 barrels) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 barrels.

(18) Cement may be sampled at the mill by any of the following methods that may be practicable as ordered:

(*a*) From the conveyor delivering to the bin at least 8 pounds of cement shall be taken from approximately each 100 barrels passing over the conveyor.

(*b*) Proper sampling tubes inserted vertically may be used for sampling cement in filled bins to a maximum depth of 10 feet. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) Sufficient cement shall be drawn from the discharge openings in filled bins to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

(19) Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample; break up lumps and remove foreign materials.

Chemical Analysis.

LOSS ON IGNITION.

(20) One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25 c. c. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900° and 1,000° C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

(21) A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent.

INSOLUBLE RESIDUE.

(22) To a 1-gram sample of cement shall be added 10 c. c. of water and 5 c. c. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 c. c. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete.

The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 c. c. of a 5 per cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1:9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

(23) A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent.

SULPHURIC ANHYDRIDE.

(24) One gram of the cement shall be dissolved in 5 c. c. of concentrated hydrochloric acid diluted with 5 c. c. of water, with gentle warming; when solution is complete, 40 c. c. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 c. c., heated to boiling, and 10 c. c. of a hot 10 per cent solution of barium chloride shall be added slowly, drop by drop from a pipette, and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulphate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulphuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulphuric anhydride instead of using a separate sample.

(25) A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2 per cent.

MAGNESIA.

(26) To 0.5 gram of the cement in an evaporating dish shall be added 10 c. c. of water to prevent lumping and then 10 c. c. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150° or even 200° C. for one-half to one hour. The residue shall be treated with 10 c. c. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered with the solution digested for 10 minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water. Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese which may be present shall be added to the filtrate (about 250 c. c.). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitation vessel and dissolved in 10 c. c. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 c. c., and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and alumi-

num, reduced in volume if need be, 1 c. c. of ammonium hydroxide shall be added, the solution brought to boiling, 25 c. c. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 c. c., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 c. c. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 c. c., 1 c. c. of a saturated solution of sodium-ammonium-hydrogen phospate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

(27) A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5 per cent.

DETERMINATION OF SPECIFIC GRAVITY.

(28) The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in figure 7. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baume, shall be used in making this determination.

(29) The flask shall be filled with either of these liquids to a point on the stem between zero and 1 c. c., and 64 grams of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck, the difference between readings is the volume displaced by 64 grams of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (c. c.)}}$$

(30) The flask during the operation shall be kept immersed in water in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5° C. The results of repeated tests should agree within 0.01.

(31) The determination of specific gravity shall be made on the cement as received. If it falls below 3.10, a second determination shall be made after igniting the sample as described in section 20.

DETERMINATION OF FINENESS.

(32) Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire and mounted without distortion on frames not less than 1½ inches below the top of the frame. The sieve frames shall be circular, approximately 8 inches in diameter, and may be provided with a pan and cover.

(33) A standard No. 200 sieve is one having nominally a 0.0029-inch opening and 200 wires per inch standardized by the United States Bureau of Standards and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 inch in width. The diameter of the wire should be 0.0021 inch, and the average diameter shall not be outside the limits 0.0019 to 0.0023 inch. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similar graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

(34) The test shall be made with 50 grams of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position, so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the upstroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 gram passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

(35) Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in paragraph 34.

(36) A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.[5]

MIXING CEMENT PASTES AND MORTARS.

(37) The quantity of dry material to be mixed at one time shall not exceed 1,000 grams nor be less than 500 grams. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 c. c. of water=1 gram). The dry materials shall be weighed, placed upon a nonabsorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of one-half minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute. During the operation of mixing, the hands should be protected by rubber gloves.

(38) The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C. (70° F.).

NORMAL CONSISTENCY.

(39) The Vicat apparatus consists of a frame A (fig. 10) bearing a movable rod, B, weighing 300 grams, one end, C, being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle, D, 1 mm. in diameter, 6 cm. long. The rod is

[5] Article 36 is to be withdrawn from these specifications, effective Jan. 1 1921.

reversible, and can be held in any desired position by a screw, E, and has midway between the ends a mark, F, which moves under a scale (graduated to millimeters) attached to the frame A. The paste is held in a conical, hard-rubber ring, G, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate, H, about 10 cm. square.

(40) In making the determination, 500 grams of cement, with a measured quantity of water, shall be kneaded into a paste, as described in section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 inches apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed

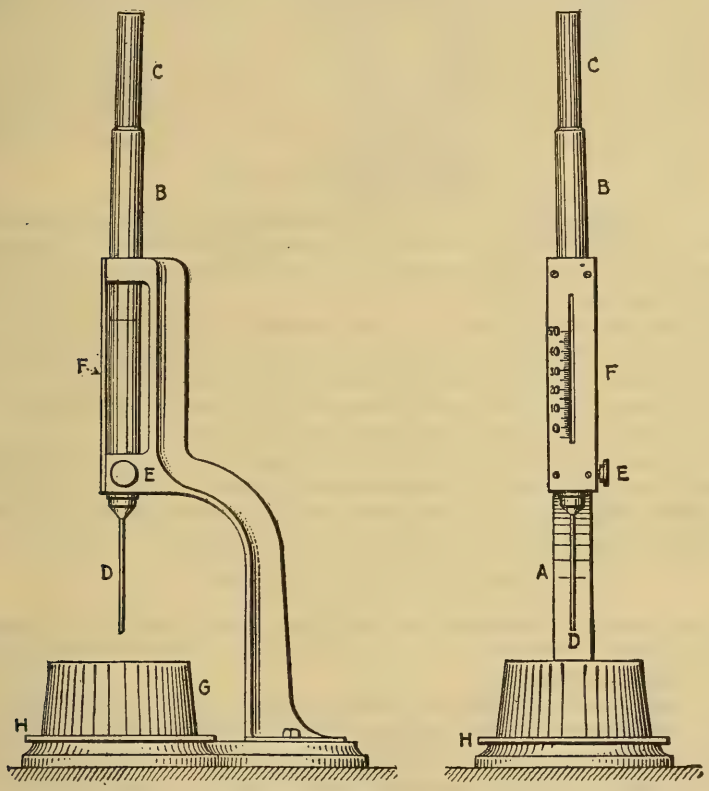


FIG. 10.—Vicat apparatus.

on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in one-half minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

(41) The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in the following table, the values being in percentage of the combined dry weights of the cement and standard sand.

Percentage of water for standard mortars.

For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.	For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.	For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.	For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.
18	9.5	21	10.0	24	10.5	27	11.0
19	9.7	22	10.2	25	10.7	28	11.2
20	9.8	23	10.3	26	10.8	29	11.3

DETERMINATION OF SOUNDNESS.

(42) A steam apparatus, which can be maintained at a temperature between 98° and 100° C., or one similar to that shown in figure 11, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

(43) A pat from cement paste of normal consistency about 3 inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 inches square, and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

(44) The pat shall then be placed in an atmosphere of steam at a temperature between 98° and 100° C. upon a suitable support 1 inch above boiling water for 5 hours.

(45) Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

DETERMINATION OF TIME OF SETTING.

(46) The following are alternate methods, either of which may be used as ordered:

(47) The time of setting shall be determined with the Vicat apparatus described in paragraph 39 (see fig. 10).

(48) A paste of normal consistency shall be molded in the hard-rubber ring G as described in paragraph 40, and placed under the rod B, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in one-half minute after being released; and the final set when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

(49) The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in figure 12 (b).

(50) The time of setting shall be determined as follows: A pat of neat cement paste with about a 3-inch diameter and one-half inch thick, with a flat top, mixed to a

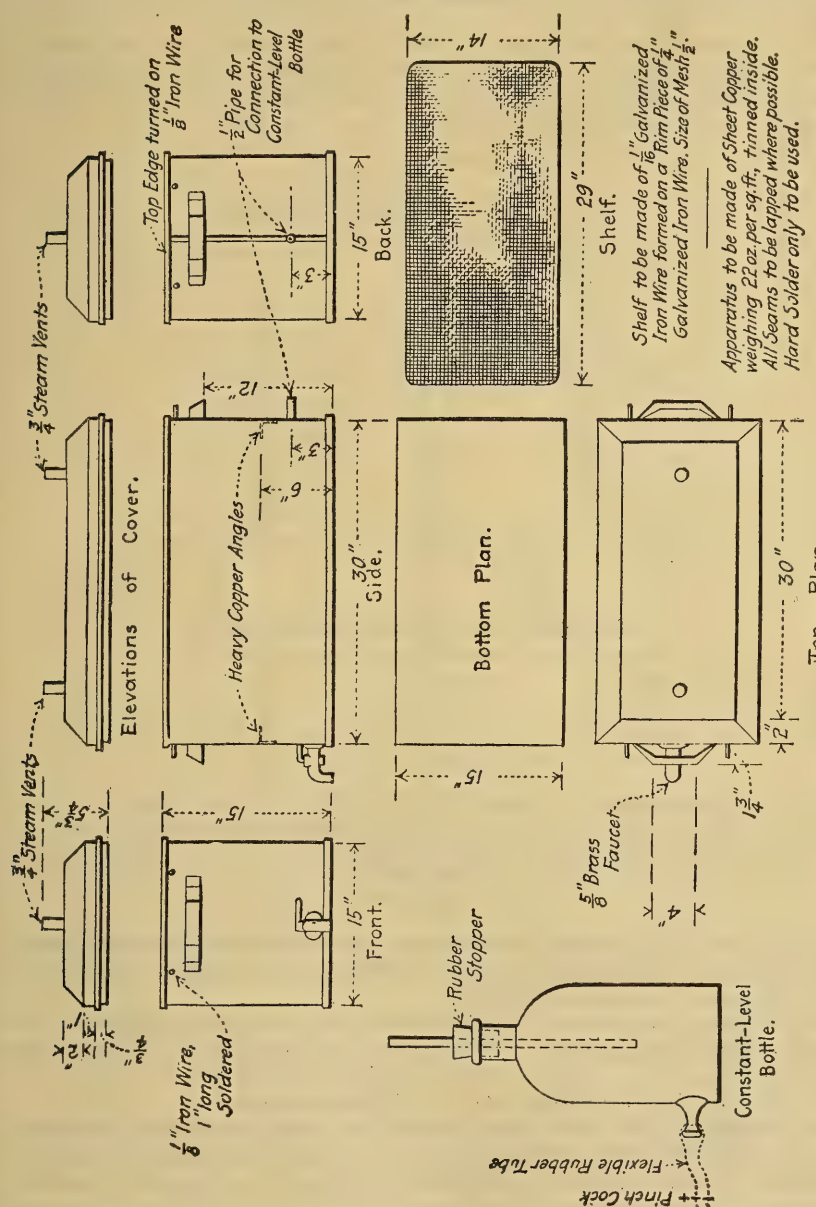


FIG. 11.—Apparatus for making soundness test of cement.

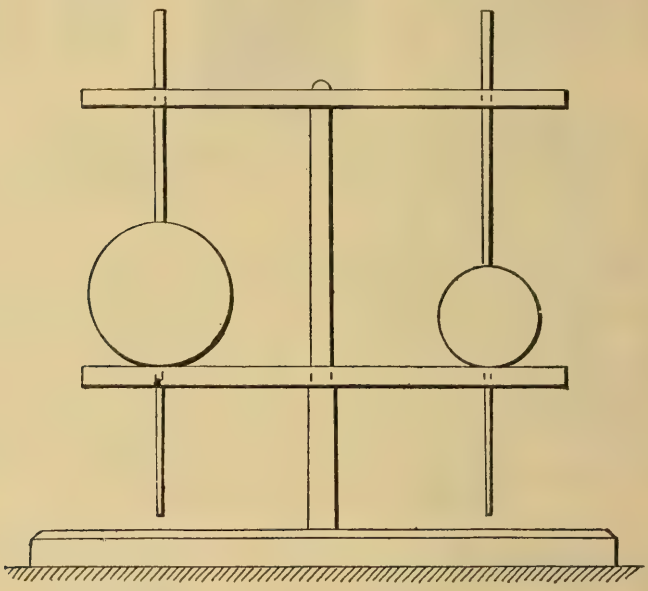
normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° F.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle one-twelfth inch in diameter, loaded to weigh one-fourth pound. The final

set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle one twenty-fourth inch in diameter, loaded to weigh 1 pound. In making the test, the needles shall be held in a vertical position, and applied lightly to the surface of the pat.

TENSION TESTS.

(51) The form of test piece shown in figure 13 shall be used. The molds shall be made of noncorroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in figure 14. Molds shall be wiped with an oily cloth before using.

(a) Pot with top surface flattened for determining time of setting by Gillmore method.



(b) Gillmore needles.

FIG. 12.

(52) The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained at a cost of 2 cents per pound, f. o. b. cars, Ottawa, Ill.

(53) This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 grams pass the No. 30 sieve after one minute continuous sieving of a 500-gram sample.

(54) The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 inch and the average diameter shall not be outside the limits of 0.0160 and 0.0170 inch.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 inch, and the average diameter shall not be outside the limits 0.0105 to 0.0115 inch.

(55) Immediately after mixing, the standard mortar shall be placed in the molds, pressed firmly with the thumbs, and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold, and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing, and smoothing off repeated.

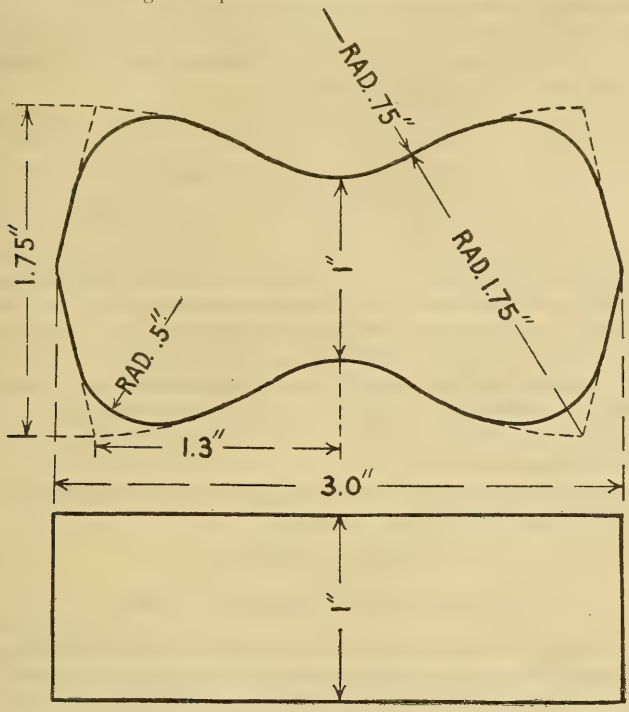


FIG. 13.—Form of briquette as recommended by the committee on uniform tests of cement of the American Society of Civil Engineers.

(56) Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 pounds per minute.

(57) Testing machines should be frequently calibrated in order to determine their accuracy.

(58) Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all tests pieces made from the same sample

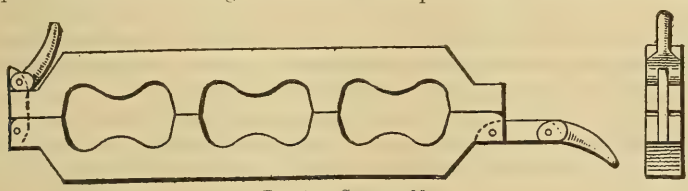


FIG. 14.—Gang mold.

and broken at the same period, shall not be considered in determining the tensile strength.

STORAGE OF TEST PIECES.

(59) The moist closet may consist of a soapstone, slate, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with

felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with nonabsorbent shelves, on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

(60) Unless otherwise specified all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

(61) The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of noncorroding material.

(62) The air and water shall be maintained as nearly as practicable at a temperature of 21° C. (70° F.).

18. TESTS FOR PAVING BRICK.

(A. S. T. M. Standard Method, Serial Designation: C 7–15.)

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side, shall be determined by the following procedure:

I. The rattler test for the purpose of determining whether the material as a whole possesses to a sufficient degree strength, toughness, and hardness.

II. Visual inspection for the purpose of determing whether the physical properties of the material as to dimensions, accuracy, and uniformity of shape and color are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

I. THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TESTS.

(1) *Place of sampling.*—In general, where a shipment of bricks involving a quantity of less than 100,000 is under consideration, the sampling shall be done at the factory prior to shipment. Bricks accepted as the result of test prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Part II, visual inspection.

(2) *Method of selecting samples.*—In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection, as provided in Part II, except that where controversy arises whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

(3) *Number of samples per lot.*—In general, one sample of 10 bricks shall be tested for every 10,000 bricks contained in the lot under consideration; but where the total quantity exceeds 100,000 the number of samples tested may be fewer than 1 per 10,000 provided that they shall be distributed as uniformly as practicable over the entire lot.

(4) *Shipment of samples.*—Samples which must be transported long distances by freight or express shall be carefully put up in packages holding not more than 12 bricks each. When more than 6 bricks are shipped in one package, it shall be so arranged as to carry two parallel rows of bricks side by side and these rows shall be

separated by a partition. In event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining 10 sound undamaged bricks.

(5) *Storage and care of samples.*—Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° F. before testing.

THE CONSTRUCTION OF THE RATTLER.

(6) *General design.*—The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame, and driving mechanism as herein described.

(7) *The barrel.*—The barrel of the machine shall be made up of the heads, head liners, staves, and stave liners.

The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ inches in diameter, and shall have a bearing 6 inches in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-inch shafts, and shall be key-seated for two keys, each one-half by three-eighths inch and spaced 90° apart. The shaft shall be a snug fit, and when keyed shall be entirely free of lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ inches in the head for the driving end of the rattler, and $11\frac{3}{8}$ inches for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ inches.

The heads shall be not less than three-fourths inch thick, nor more than seven-eighths inch thick. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ inches in diameter. Each head shall be provided with flanges not less than three-fourths of an inch thick and extending outward $2\frac{1}{2}$ inches from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge so as to provide for two three-fourths-inch bolts at each end of each stave, said slots to be thirteen-sixteenths of an inch wide and $2\frac{3}{4}$ inches center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace three-eighths of an inch thick, extending down the outward side of the head not less than 2 inches.

There shall be for each head a cast-iron head liner 1 inch in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ inches in diameter. This head liner shall be fastened to the head by seven five-eighths-inch cap screws, through the head from the outside. Whenever these head liners become worn down one-half inch below their initial surface level at any point of their surface, they shall be replaced with new ones. The metal of these head liners shall be hard machinery iron and should contain not less than 1 per cent of combined carbon.

The staves shall be made of 6-inch medium-steel structural channels $27\frac{1}{4}$ inches long and weighing 15.5 pounds per linear foot. The staves shall have two holes thirteen-sixteenths inch in diameter, drilled in each end, the center line of the holes being 1 inch from the end and $1\frac{3}{8}$ inches either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed five-sixteenths of an inch.

The interior or flat side of each stave shall be protected by a liner three-eighths of an inch thick by $5\frac{1}{2}$ inches wide by $19\frac{3}{4}$ inches long. The liner shall consist of medium-steel plate, and shall be riveted to the channel by three one-half-inch rivets, one of

which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 inches from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once reriveted.

Any test at the expiration of which a stave liner is found detached from the stave or seriously out of position shall be rejected. When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged with 400 pounds of shot of the same sizes and in the same proportions as provided in section 9, and shall then be run for 18,000 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive but not contiguous, for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative condition of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 inches long, inside measurement, between headliners. The liners of the staves shall be so placed as to drop between the headliners. The staves shall be bolted tightly to the heads by four three-fourths inch bolts, and each bolt shall be provided with a lock nut, and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

(8) *The frame and driving mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The countershaft upon which the driving pinion is mounted shall not be less than $1\frac{15}{16}$ inches in diameter, with bearing not less than 6 inches in length. If a belt drive is used the pulley shall not be less than 18 inches in diameter and $6\frac{1}{2}$ inches in face. A belt at least 6 inches in width properly adjusted, to avoid unnecessary slipping, should be used.

(9) *The abrasive charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 inches in diameter and shall weigh approximately 7.5 pounds (3.40 kg.) each. Ten spheres of this size shall be used.

These shall be weighed separately after each 10 tests, and if the weight of any large sphere falls to 7 pounds (3.175 kg.) it shall be discarded and a new one substituted; provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller spheres shall be 1.875 inches in diameter and shall weigh approximately 0.95 pound (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 pounds as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole

1.75 inches in diameter, drilled in an iron plate one-fourth inch in thickness, or weigh less than 0.75 pound (0.34 kg.). Further, the small spheres shall be tested, by passing them over the above plate or by weighing, after every 10 tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres; provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective, it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon	Not under 2.50 per cent.
Graphitic carbon	Not over 0.25 per cent.
Silicon	Not over 1.00 per cent.
Manganese	Not over 0.50 per cent.
Phosphorus	Not over 0.25 per cent.
Sulphur	Not over 0.08 per cent.

For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user, before introducing into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

(10) *The brick charge.*—The number of bricks per test shall be 10 for all bricks of so-called "block-size," whose dimensions fall between 8 and 9 inches in length, 3 and $3\frac{3}{4}$ inches in breadth, and $3\frac{3}{4}$ and $4\frac{1}{4}$ inches in thickness.[6] No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

(11) *Speed and duration of revolution.*—The rattler shall be rotated at a uniform rate of not less than 29.5 nor more than 30.5 revolutions per minute, and 1,800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed 10 revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

(12) *The scales.*—The scales must have a capacity of not less than 300 pounds, and must be sensitive to 0.5 ounce, and must be tested by a standard test weight at intervals of not less than every 10 tests.

(13) *The results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick, any piece weighing less than 1 pound shall be rejected.

(14) *The records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made:

1. The name of the person, firm, or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street, or contract, which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were tested.

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[6] Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

7. The drying treatment given before testing, if any.
8. The length, breadth, and thickness of the bricks.
9. The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
10. The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
11. The total weight of the shot charge after its last standardization.
12. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them right at the beginning of the test.
13. Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of stave liners.
14. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the indicator.
15. Certificate of the operator as to number of stops and starts made in each test.
16. The initial collective weight of the ten bricks composing the charge and their collective weight after rattling.
17. The loss calculated in percentage of the initial weight; and the calculation itself.
18. The number of broken bricks and remarks upon the portions which were included in the final weighing.
19. General remarks upon the test and any irregularities occurring in its execution.
20. The date upon which the test was made.
21. The location of the rattler, upon which the test was made, and name of the owner.
22. The certificate of the operator that the test was made under the specifications of the American Society for Testing Materials and that the record is a true record.
23. The signature of the operator or person responsible for the test.
24. The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicates, but the original record shall always be preserved intact and complete.

For the convenience of the public, the accompanying blank form, which provides space for the necessary data, is furnished and its use recommended.

Serial No. .....

Report of Standard Rattler Test of Paving Brick.

Identification data.

Name of the firm furnishing sample.....
Name of the firm manufacturing sample.....
Street or job which sample represents.....
Brands or marks on the brick.....
Quantity furnished..... Drying treatment.....
Date received..... Date tested.....
Length..... Breadth..... Thickness.....

Standardization data.

Weight of charge (after standardization).	Condition of lock nuts on staves.	Condition of staves.	Number and position of fresh stave liners.	Repairs (not any repairs affecting the condition of the barrel).
10 large spheres.....	.....	.....	.....	.....
Small spheres.....	.....	.....	.....	.....
Total.....	.....	.....	.....	.....

Number of charges tested since last inspection.....

Running data.

	Time readings.			Revolution counter readings.	Running notes, stops, etc.
	Hours.	Minutes.	Seconds.		
Beginning of test.....	.....	.....	.....	.....	.....
Final reading.....	.....	.....	.....	.....	.....

Weights and calculations.

		Percentage loss (the calculation must appear).
Initial weight of 10 bricks.....	.....	.....
Final weight of same.....	.....	.....
Loss of weight.....	.....	.....

Number of broken bricks and remarks on same.....

I certify that the foregoing test was made under the specifications of the American Society for Testing Materials, and is a true record.

(Signature of tester).....

Date.....
Location of laboratory.....

A CCEPTANCE AND REJECTION OF MATERIAL.

(15) *Basis of acceptance or rejection.*—Paving bricks shall not be judged for acceptance or rejection by the results of individual tests, but by the average of no less than five tests. Where a lot of bricks fail to meet the required average, it shall be optional with the buyer whether the bricks shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in section 16.

(16) *Range of fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variations in the bricks and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than 2 per cent, then the portion of the lot represented by that test shall be at once resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than 2 per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick two or more tests exceed the permissible maximum, then the buyer may at his option reject the entire lot, even though the average of all the tests executed may be within the required limits.

(17) *Fixing of standards.*—The percentage of loss which may be taken as the standard will not be fixed in these specifications, and shall remain within the province of the contracting parties. For the information of the public, the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	General average loss.	Maximum permissible loss.
	Per cent.	*Per cent.*
For bricks suitable for heavy traffic	22	24
For bricks suitable for medium traffic	24	26
For bricks suitable for light traffic	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer and should be governed by the kind and amount of traffic to be carried and the quality of paving bricks available.

(18) *Culling and retesting.*—Where, under sections 15 and 16, a lot or portion of a lot of bricks is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

(19) *Payment of cost of testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also section 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it shall be paid by the seller, whether the material is finally accepted or rejected.

II. VISUAL INSPECTION.

It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use and prior to or during laying, to cull out and reject upon the following grounds:

(20) All bricks which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

(21) All bricks which are cracked in such a degree as to produce defects such as are defined in section 20, either from shocks received in shipment and handling or from defective conditions of manufacture, especially in drying, burning, or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

(22) All bricks which are so offsize, or so misshapen, bent, twisted, or kiln marked, that they will not form a proper surface as defined by the paving specifications, or align with other bricks without making joints other than those permitted in the paving specifications.

(23) All bricks which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in section 2, and if in either or both tests the bricks fall beyond the maximum rattler losses permitted under the specifications, then all bricks having the same objectionable appearance may be excluded, and the seller shall pay for the cost of the test. But if under such procedure the bricks which have been tested as objectionable shall pass the rattler test, both tests falling within the permitted maximum, then the buyer can not exclude the class of material represented by this test and he shall pay for the cost of the test.

(24) All bricks which differ so markedly in color from the type or average of the shipment as to make the resultant pavement checkered or disagreeably mottled in appearance. This section shall not be held to apply to the normal variations in color which may occur in the product of one plant among bricks, which will meet the rattler test as referred to in sections 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

Absorption.[7]—The absorption test shall be made on five rattled brick, which shall be immersed in water for 48 hours. The absorption shall be expressed in per cent of the weight of the brick before immersion.

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[7] Not a part of the A. S. T. M. standard method.

TESTS FOR BITUMINOUS ROAD MATERIALS.

19. DETERMINATION OF SPECIFIC GRAVITY OF BITUMINOUS MATERIALS.

A. HYDROMETER METHOD (USED FOR THIN FLUID BITUMENS).

The specific gravity of thin fluid bituminous road materials is determined at 25° C. as compared with water at that temperature. This may be done with the above-mentioned apparatus by first pouring a sufficient quantity of the material into the tin cup, which is then placed in the large dish containing cold or warm water as occasion may require. The material in the cup should be stirred with the thermometer until

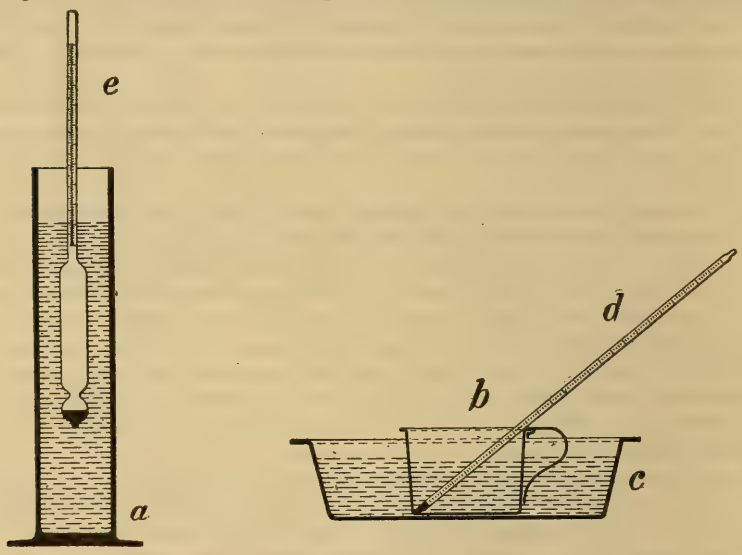


FIG. 15.—Hydrometer method of determining specific gravity.

it is brought to a temperature of 25° C., after which it should be immediately poured into the hydrometer jar and its gravity determined by means of the proper hydrometer. In case the hydrometer sinks slowly, owing to the viscosity of the material, it should be given sufficient time to come to a definite resting point, and this point should be checked by raising the hydrometer and allowing it to sink a second time. The hydrometer should never be pushed below the point at which it naturally comes to rest until the last reading has been made. It may then be pushed below the reading for a distance of three or four of the small divisions on the scale, whereupon it should immediately begin to rise. If it fails to do so, the material is too viscous for the hydrometer method, and the pycnometer method should be employed.

The direct specific gravity reading obtained by the foregoing method is based upon water at 15.5° C. taken as unity. For all practical purposes this reading may be corrected to water at 25° C., considered as unity, by multiplying it by 1.002. Thus: Specific gravity 25° C./25° C.=specific gravity 25° C./15.5° C.×1.002.

B. PYCNOMETER METHOD (USED FOR VISCOUS FLUID AND SEMISOLID BITUMENS AND EMULSIONS).

The inconvenience and difficulty of employing the ordinary narrow neck pycnometer when determining the specific gravity of viscous fluid and semisolid bitumens has led to the use of a special form shown in figure 16.

U. S. DEPARTMENT OF AGRICULTURE BULLETIN NO. 949.

Standard and Tentative Methods of Sampling and Testing Highway Materials.

Errata.

P. 37. Change the formula for specific gravity to read

$$\text{Specific gravity } 25^\circ\text{C.}/25^\circ\text{C.} = \frac{c-a}{(b-a)-(d-c)}$$

s.

This pycnometer consists of a conical or Erlenmeyer-shaped flask about 4.5 cm. high, 4.0 cm. diameter at bottom, and 2.5 cm. diameter at the mouth. It is carefully ground to receive an accurately fitting solid glass stopper with a hole about 1 mm. bore in place of the usual capillary opening. The lower surface of this stopper is made concave to allow air bubbles to escape through the bore. The depth of the cup-shaped depression is 4.8 mm. at the center. The flask has a capacity of about 25 c. c. and weighs when empty about 25 grams. Its principal advantages are (1) that any desired amount of bitumen may be poured in without touching the sides above the desired level; (2) it is easily cleaned; (3) on account of the 1.0 mm. bore the stopper can be easily inserted when the flask is filled with a viscous oil.

When working with semisolid bitumens which are too soft to be broken and handled in fragments, the following method of determining their specific gravity is employed:

The clean, dry pycnometer is first weighed empty, and this weight is called *a*. It is then filled in the usual manner with freshly distilled water at 25° C., and the weight is again taken and called *b*. A small amount of the bitumen should be placed in the spoon and brought to a fluid condition by the gentle application of heat, with care that no loss by evaporation occurs. When sufficiently fluid, enough is poured into the dry pycnometer, which may also be warmed, to fill it about half full without allowing the material to touch the sides of the tube above the desired level. The flask and contents are then allowed to cool to room temperature, after which the tube is carefully weighed with the stopper. This weight is called *c*. Distilled water, at 25° C., is then poured in until the pycnometer is full. After this the stopper is inserted, and the whole cooled to 25° C. by a 30-minute immersion in a beaker of distilled water maintained at this temperature. All surplus moisture is then removed with a soft cloth, and the pycnometer and contents are weighed. This weight is called *d*. From the weights obtained the specific gravity of the bitumen may be readily calculated by the following formula:

$$\text{Specific gravity } 25^\circ \text{ C.}/25^\circ \text{ C.} = \frac{(b-a)-(d-c)}{c-a}$$

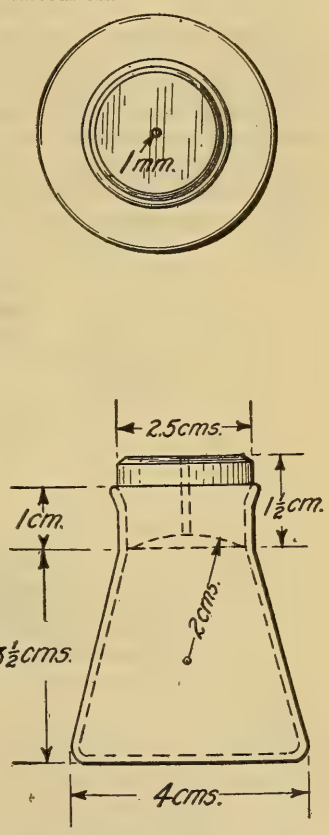


FIG. 16.—Hubbard-Carmick pycnometer. (Dimensions only approximate.)

Both *a* and *b* are constants and need be determined but once. It is therefore necessary to make but two weighings for each determination after the first. Results obtained according to the method given above are accurate to within 2 units in the third decimal place, while the open-tube method is accurate to the second decimal place only.

The specific gravity of fluid bitumens may be determined in the ordinary manner with this pycnometer by completely filling it with the material and dividing the weight of the bitumen thus obtained by that of the same volume of water.

The pycnometer may be readily cleaned by placing it in a hot-air bath until the bitumen is sufficiently fluid to pour. As much is drained out as possible and the interior swabbed with a piece of cotton waste. It is then rinsed clean with a little carbon disulphide, and after drying is again ready for use.

C. DISPLACEMENT METHOD (USED FOR HARD SOLID BITUMENS).

For materials which are hard enough to be broken and handled in fragments at room temperature, the following method will prove convenient. A small fragment of the bitumen (about 1 c. c.) is suspended by means of a silk thread from the hook on one of the pan supports, about 1½ inches above the pan, and weighed. This weight is called *a*. It is then weighed immersed in water at 25° C., as shown in figure 17, and this weight is called *b*. The specific gravity may then be calculated by means of the following formula:

$$\text{Specific gravity}=\frac{a}{a-b}$$

20. DETERMINATION OF BITUMEN SOLUBLE IN CARBON DISULPHIDE.

This test consists in dissolving the bitumen in carbon disulphide and recovering any insoluble matter by filtering the solution through an asbestos felt. The form of Gooch crucible best adapted for the determination is 4.4 cm. wide at the top, tapering to 3.6 cm. at the bottom, and is 2.5 cm. deep.

For preparing the felt the necessary apparatus is arranged as shown in figure 18, in which *a* is the filtering flask, *b* a rubber stopper, *c* the filter tube, and *d* a section

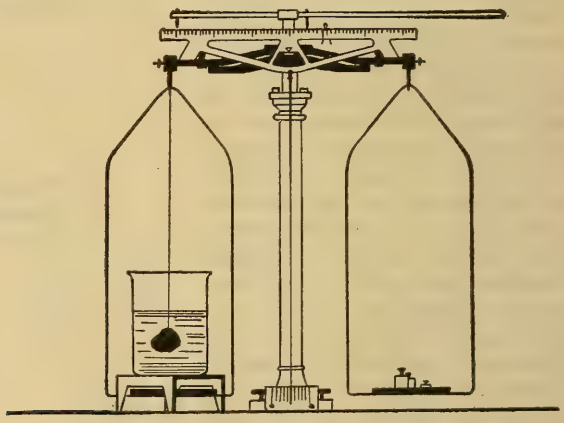


FIG. 17.—Displacement method of determining specific gravity.

of rubber tubing which tightly clasps the Gooch crucible, *e*. The asbestos is cut with scissors into pieces not exceeding 1 cm. in length, after which it is shaken up with just sufficient water to pour easily. The crucible is filled with the suspended asbestos, which is allowed to settle for a few moments. A light suction is then applied to draw off all the water and leave a firm mat of asbestos in the crucible. More of the suspended material is added, and the operation is repeated until the felt is so dense that it scarcely transmits light when held so that the bottom of the crucible is between the eye and the source of light. The felt should then be washed several times with water and drawn firmly against the bottom of the crucible by an increased suction. The crucible is removed to a drying oven for a few minutes, after which it is ignited at red heat over a Bunsen burner, cooled in a desiccator, and weighed.

From 1 to 2 grams of bitumen or about 10 grams of an asphalt topping or rock asphalt is now placed in the Erlenmeyer flask, which has been previously weighed, and the accurate weight of the sample is obtained. One hundred cubic centimeters of chemically pure carbon disulphide is poured into the flask in small portions, with continual agitation, until all lumps disappear and nothing adheres to the bottom. The flask is then corked and set aside for 15 minutes.

After being weighed, the Gooch crucible containing the felt is set up over the dry-pressure flask, as shown in figure 18, and the solution of bitumen in carbon disulphide is decanted through the felt without suction by gradually tilting the flask, with care not to stir up any precipitate that may have settled out. At the first sign of any sediment coming out, the decantation is stopped and the filter allowed to drain. A small amount of carbon disulphide is then washed down the sides of the flask, after which the precipitate is brought upon the felt and the flask scrubbed, if necessary, with a feather or "policeman" to remove all adhering material. The contents of the crucible are washed with carbon disulphide, until the washings run colorless. Suction is then applied until there is practically no odor of carbon disulphide in the crucible, after which the outside of the crucible is cleaned with a cloth moistened with a small amount of the solvent. The crucible and contents are dried in the hot-air oven at 100° C. for about 20 minutes, cooled in a desiccator, and weighed. If any appreciable amount of insoluble matter adheres to the flask, it should also be dried and weighed, and any increase over the original weight of the flask should be added to the weight of insoluble matter in the crucible. The total weight of insoluble material may include both organic and mineral matter. The former, if present, is burned off by ignition at a red heat until no incandescent particles remain, thus leaving the mineral matter or ash, which can be weighed on cooling. The difference between the total weight of material insoluble in carbon disulphide and the weight of substance taken equals the total bitumen, and the percentage weights are calculated and reported as total bitumen, and organic and inorganic matter insoluble, on the basis of the weight of material, taken for analysis.

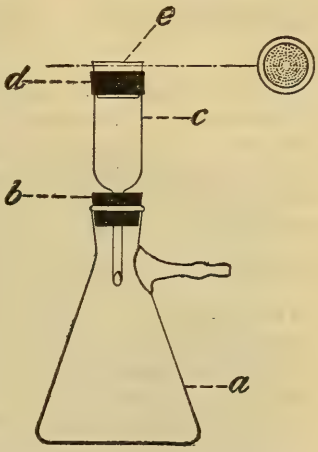


FIG. 18.—Apparatus for determining soluble bitumen.

This method is quite satisfactory for straight oil and tar products, but where certain natural asphalts are present it will be found practically impossible to retain all of the finely divided mineral matter on an asbestos felt. It is, therefore, generally more accurate to obtain the result for total mineral matter by direct ignition of a 1-gram sample in a platinum crucible or to use the result for ash obtained in the fixed carbon test. The total bitumen is then determined by deducting from 100 per cent the sum of the percentages of total mineral matter and organic matter insoluble. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash from the fixed carbon determination with a few drops of ammonium carbonate solution, drying at 100° C., then heating for a few minutes at a dull red heat, cooling, and weighing again.

When difficulty in filtering is experienced—for instance, when Trinidad asphalt is present in any amount—a period of longer subsidence than 15 minutes is necessary, and the following method proposed by the Committee on Standard Tests for Road Materials of the American Society for Testing Materials is recommended:

From 2 to 15 grams (depending on the richness in bitumen of the substance) is weighed into a 150-cubic centimeter Erlenmeyer flask, the tare of which has been previously ascertained, and treated with 100 c. c. of carbon disulphide. The flask is then loosely corked and shaken from time to time until practically all large particles of the material have been broken up, when it is set aside and not disturbed for 48 hours. The solution is then decanted off into a similar flask that has been previously weighed, as much of the solvent being poured off as possible without disturbing the

residue. The first flask is again treated with fresh carbon disulphide and shaken as before, when it is put away with the second flask and not disturbed for 48 hours.

At the end of this time the contents of the two flasks are carefully decanted off upon a weighed Gooch crucible fitted with an asbestos filter, the contents of the second flask being passed through the filter first. The asbestos filter shall be made of ignited long-fiber amphibole, packed in the bottom of a Gooch crucible to the depth of not over one-eighth of an inch. After passing the contents of both flasks through the filter, the two residues are shaken with more fresh carbon disulphide and set aside for 24 hours without disturbing, or until it is seen that a good subsidation has taken place, when the solvent is again decanted off upon the filter. This washing is continued until the filtrate or washings are practically colorless,

The crucible and both flasks are then dried at 125° C. and weighed. The filtrate containing the bitumen is evaporated, the bituminous residue burned, and the weight of the ash thus obtained added to that of the residue in the two flasks and the crucible. The sum of these weights deducted from the weight of substance taken gives the weight of bitumen extracted.

21. DETERMINATION OF BITUMEN INSOLUBLE IN CARBON TETRACHLORIDE.

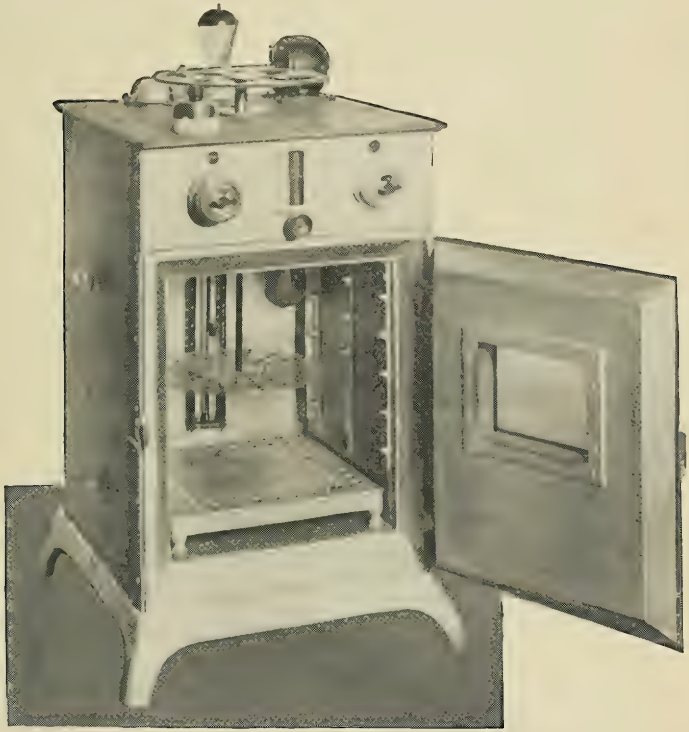
This determination is conducted in exactly the same manner as described under "Determination of bitumen soluble in carbon disulphide," using 100 c. c. of chemically pure carbon tetrachloride as a solvent in place of carbon disulphide.

The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100, as described under "Determination of bitumen insoluble in paraffin naphtha."

22. DETERMINATION OF BITUMEN INSOLUBLE IN PARAFFIN NAPHTHA.

This determination is made in the same general manner as the total bitumen determination, except that 100 c. c. of 86° to 88° B. paraffin naphtha, at least 85 per cent distilling between 35° C. and 65° C., is employed as a solvent instead of carbon disulphide. Considerable difficulty is sometimes experienced in breaking up some of the heavy semisolid bitumens; the surface of the material is attacked, but it is necessary to remove some of the insoluble matter in order to expose fresh material to the action of the solvent. It is, therefore, advisable to heat the sample after it is weighed, allowing it to cool in a thin layer around the lower part of the flask. If difficulty is still experienced in dissolving the material, a rounded glass rod will be found convenient for breaking up the undissolved particles. Not more than one-half of the total amount of naphtha required should be used until the sample is entirely broken up. The balance of the 100 c. c. is then added, and the flask is twirled a moment in order to mix the contents thoroughly, after which it is corked and set aside for 30 minutes.

In making the filtration the utmost care should be exercised to avoid stirring up any of the precipitate, in order that the filter may not be clogged and that the first decantation may be as complete as possible. The sides of the flask should then be quickly washed down with naphtha and, when the crucible has drained, the bulk of insoluble matter is brought upon the felt. Suction may be applied when the filtration by gravity almost ceases, but should be used sparingly, as it tends to clog the filter by packing the precipitate too tightly. The material on the felt should never be allowed to run entirely dry until the washing is completed, as shown by the colorless filtrate. When considerable insoluble matter adheres to the flask no attempt should be made to remove it completely. In such cases the adhering material is merely washed until free from soluble matter, and the flask is dried with the crucible at 100° C.



ELECTRIC OVEN FOR VOLATILIZATION TEST.

for about one hour, after which it is cooled and weighed. The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100.

The difference between the material insoluble in carbon disulphide and in the naphtha is the bitumen insoluble in the latter. Thus, if in a certain instance it is found that the material insoluble in carbon disulphide amounts to 1 per cent and that 10.9 per cent is insoluble in naphtha, the percentage of bitumen insoluble would be calculated as follows:

$$\frac{\text{Bitumen insoluble in naphtha}}{\text{Total bitumen}}=\frac{10.9-1}{100-1}=\frac{9.9}{99}=10 \text{ per cent.}$$

23. VOLATILIZATION TEST.

An oven is used that will give a uniform temperature throughout all parts where samples are placed. A gas oven of the type shown in figure 19 or an electric oven of proper design (see Pl. I) may be used. The bulb of one of the thermometers is immersed in a sample of some fluid nonvolatile bitumen, while the other is kept in air at the same level. The first thermometer serves to show the temperature of the samples during the test, while the latter gives prompt warning of any sudden changes in temperature due to irregularities in the heat.

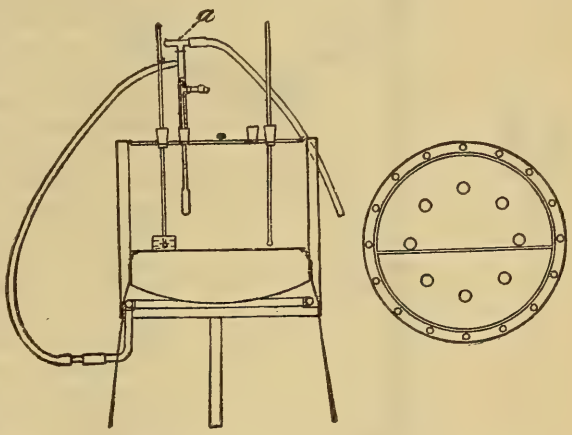


FIG. 19.—New York Testing Laboratory oven.

Before making the test the interior of the oven should show a temperature of 163° C. as registered by the thermometer in air. A tin box 5½ cm. in diameter and 3½ cm. deep (American Can Co., gill type, deep pattern ointment box) is accurately weighed after carefully wiping with a towel to remove any grease or dirt. About 50 grams of the material to be tested is then placed in the box. The material may then be weighed on a rough balance, if one is at hand, after which the accurate weight, which should not vary more than 0.2 gram from the specified amount, is obtained. It may be necessary to warm some of the material in order to handle it conveniently, after which it must be allowed to cool before determining the accurate weight.

The sample should now be placed in the oven, where it is allowed to remain for a period of five hours, during which time the temperature as shown by the thermometer in bitumen should not vary at any time more than 2° C. The sample is then removed from the oven, allowed to cool, and reweighed. From the difference between this weight and the total weight before heating the percentage of loss on the amount of material taken is calculated.

The general appearance of the residue should be noted, especially with regard to any changes which the material may have undergone. Some relative idea of the amount of hardening which has taken place may be obtained from the results of a float or penetration test made on the residue, as compared with the results of the same test on the original sample. It is also frequently desirable to make the specific gravity and other tests on the residue for the purpose of identifying or ascertaining the character of the base used in the preparation of cut-back products. Before any tests are made on the residue, it should be melted and thoroughly stirred while cooling.

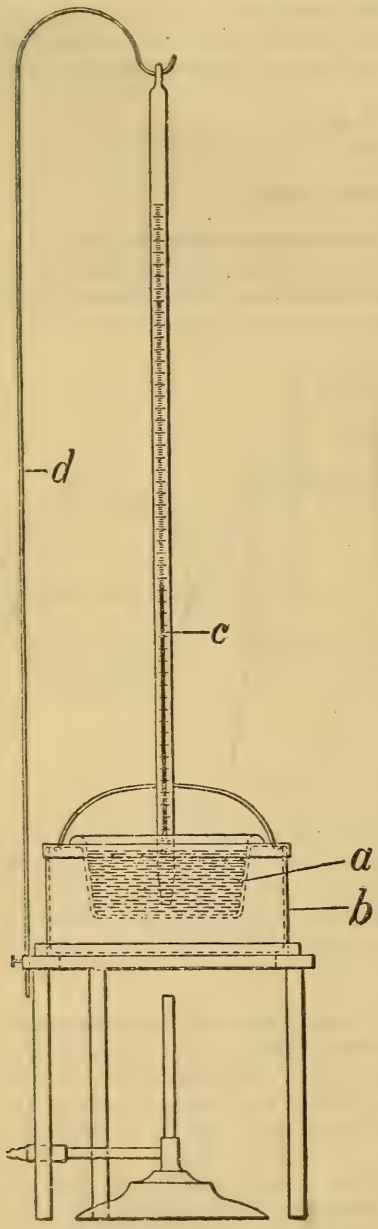
Highly volatile and nonvolatile materials should not be subjected to this test at the same time in the same oven owing to a tendency on the part of the latter to absorb some of the volatile products of the former.

24. FLASH AND BURNING POINT TESTS.

The open-cup oil tester consists of a brass oil cup, *a*, (Fig. 20) of about 100 c. c. capacity. The outer vessel, *b*, serves as an air jacket. No glass cover is used in the open-cup method. A suitable thermometer, *c*, is suspended from the wire support, *d*, directly over the center of the cup so that its bulb is entirely covered with oil but does not touch the bottom of the cup. The testing flame is obtained from a jet of gas passed through a piece of glass tubing, and should be about 5 millimeters in length.

The test is made by first filling the oil cup with the material under examination to within about 5 m. m. of the top. The Bunsen flame is then applied in such a manner that the temperature of the material in the cup is raised at the rate of 5° C. per minute. From time to time the testing flame is brought almost in contact with the surface of the oil. A distinct flicker or flash over the entire surface of the oil shows that the flash point is reached and the temperature at this point is taken. It will usually be found that the flash point as determined by the open-cup method is somewhat higher than by the closed-cup method, for the same material.

The burning point of the material is obtained by continuing the test and noting that temperature at which it ignites and burns. The flame should then be extinguished by means of a metal cover supplied with the instrument.



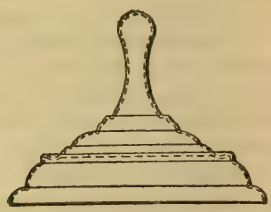


FIG. 20.—Open-cup oil tester.

25. FLOAT TEST FOR CONSISTENCY.

The float apparatus consists of two parts (see fig. 21), an aluminum float or saucer, *a*, and a conical brass collar, *b*. The two parts are made separately, so that one float may be used with a number of brass collars.

In making the test the brass collar is placed with the small end down on the brass plate, which has been previously amalgamated with mercury by first rubbing it with a dilute solution of mercuric chloride or nitrate and then with mercury. A small quantity of the material to be tested is heated in the metal spoon until quite fluid, with care that it suffers no appreciable loss by volatilization and that it is kept free from air bubbles. It is then poured into the collar in a thin stream until slightly more than level with the top. The surplus may be removed, after the material has cooled to room temperature, by means of a spatula or steel knife which has been slightly heated. The collar and plate are then placed in one of the tin cups containing ice

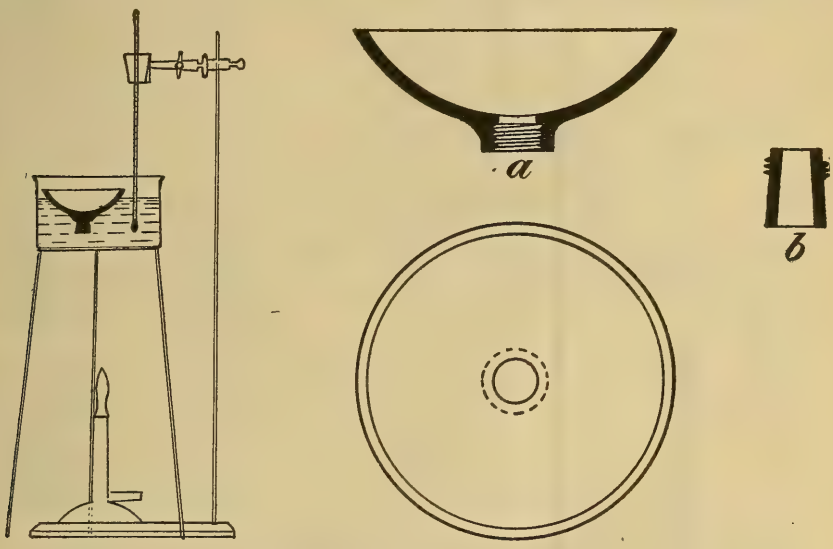


FIG. 21.—New York Testing Laboratory float apparatus.

water maintained at 5° C., and left in this bath for at least 15 minutes. Meanwhile the other cup is filled about three-fourths full of water and placed on the tripod, and the water is heated to any desired temperature at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than one-half a degree centigrade from the temperature selected. After the material to be tested has been kept in the ice water for at least 15 minutes, the collar with its contents is removed from the plate and screwed into the aluminum float, which is then immediately floated in the warmed bath. As the plug of bituminous material becomes warm and fluid, it is gradually forced upward and out of the collar, until water gains entrance to the saucer and causes it to sink.

The time in seconds between placing the apparatus on the water and when the water breaks through the bitumen is determined by means of a stop watch and is taken as a measure of the consistency of the material under examination.

26. FIXED CARBON DETERMINATION.

This determination is made in accordance with the method described for coal in the Journal of the American Chemical Society, 1899, volume 21, page 1116. One gram of the material is placed in a platinum crucible weighing from 20 to 30 grams and having a tightly fitting cover. It is then heated for seven minutes over the full flame of a Bunsen burner, as shown in figure 22. The crucible should be supported on a platinum triangle with the bottom from 6 to 8 cm. above the top of the burner. The flame should be fully 20 cm. high when burning freely, and the determination should be made in a place free from drafts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon, excepting in the case of some of the more fluid bitumens, when the under surface of the cover may be quite clean.

The crucible is removed to a desiccator and when cool is weighed, after which the cover is removed, and the crucible is placed in an inclined position over the Bunsen burner and ignited until nothing but ash remains. Any carbon deposited on the cover is also burned off. The weight of ash remaining is deducted from the weight of the residue after the first ignition of the sample. This gives the weight of the so-called fixed or residual carbon, which is calculated on a basis of the total weight of the sample, exclusive of mineral matter. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash with a few drops of ammonium carbonate solution, drying at 100° C. then heating for a few minutes at a dull red heat, cooling and weighing.

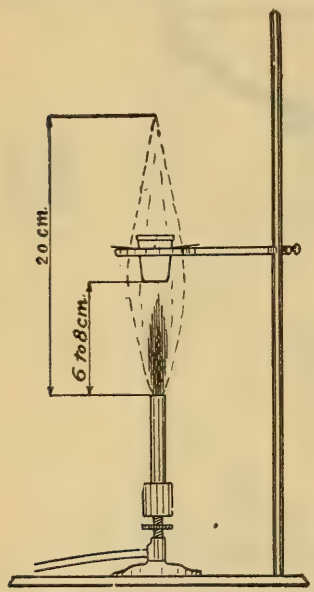


FIG. 22.—Apparatus for determining fixed carbon.

An excellent form of crucible for this test has a cover with a flange 4 mm. wide, fitting tightly over the outside of the crucible, and weighs complete about 25 grams. Owing to sudden expansion in burning some of the more fluid bitumens, it is well to hold the cover down with the end of the tongs until the most volatile products have burned off.

Some products, particularly those derived from Mexican petroleum, show a tendency to suddenly expand and foam over the sides of the crucible in making this determination, and no method of obviating this trouble without vitiating the result has thus far been forthcoming. Recent experiments in the laboratory of the Bureau of Public Roads indicate that the difficulty may be overcome by placing a small piece of platinum gauze over the sample and about midway of the crucible. The gauze should be so cut or bent as to touch the sides of the crucible at all points, and is of course weighed in place in the crucible before and after ignition.

27. SPECIFIC VISCOSITY DETERMINATION.

The viscosity of fluid bituminous road materials may be determined at any suitable temperature by means of the Engler viscosimeter. This apparatus is shown in figure 23, and may be described as follows: *a*, is a brass vessel for holding the material to be tested, and may be closed by the cover, *b*. To the conical bottom of *a* is fitted a conical outflow tube, *c*, exactly 20 mm. long, with a diameter at the top of 2.9 mm. and at the bottom of 2.8 mm. This tube can be closed and opened by the pointed hardwood stopper, *d*. Pointed metal projections are placed on the inside of *a* at

equal distances from the bottom and serve for measuring the charge of material, which is 240 c. c. The thermometer *e* is used to ascertain the temperature of the material to be tested. The vessel *a* is surrounded by a brass jacket, *f*, which holds the material used as a heating bath, either water or cottonseed oil, according to the temperature at which the test is to be made. A tripod, *g*, serves as a support for the apparatus and also carries a ring burner *h*, by means of which the bath is directly heated. The measuring cylinder of 100 c. c. capacity, which is sufficiently accurate for work with road materials, is placed directly under the outflow tube.

As all viscosity determinations should be compared with that of water at 25° C., the apparatus should be previously calibrated as follows: The cup and outlet tube should first be scrupulously cleaned. A piece of soft tissue paper is convenient for cleaning the latter. The stopper is then inserted in the tube and the cup filled with water at 25° C. to the top of the projections. The measuring cylinder should be placed directly under the outflow tube so that the material, upon flowing out, will not touch the sides, and the stopper may then be removed. The time required both for 50 and 100 c. c. to run out should be ascertained by means of a stop watch, and the results so obtained should be checked a number of times. The time required for 50 c. c. of water should be about 11 seconds and for 100 c. c. about 22.8 seconds.

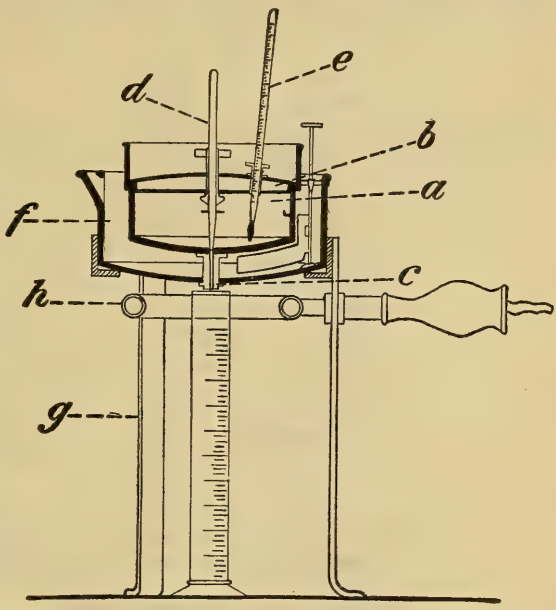


FIG. 23.—Engler viscosimeter.

Bituminous road materials are tested in the same manner as water, and the temperature at which the test is made is controlled by the bath. The material should be brought to the desired temperature and maintained there for at least three minutes before making the test. The results are expressed as specific viscosity compared with water at 25° C., as follows:

$$\text{Specific viscosity at A° C.} = \frac{\text{seconds for passage of given volume at A°C.}}{\text{seconds for passage of same volume of water at 25° C.}}$$

28. DETERMINATION OF PERCENTAGE OF RESIDUE OF DESIRED PENETRATION.

Fifty grams of the oil are placed in a 3-ounce deep, seamless tin box; the box is placed in a sand bath and heated over a Bunsen burner. A thermometer is suspended in the oil, the bulb not touching the bottom of the box. The temperature of the oil is kept at from 249° C. (480° F.) to 260° C. (500° F.), and the oil is stirred from time to time with the thermometer to prevent overheating in any part. Depending upon the nature of the oil, as usually indicated by its flash, consistency at 25° C. (77° F.) and specific gravity, the operator can with experience tell about what percentage it will be necessary to evaporate before cooling and taking a penetration of the residue.

It is sometimes necessary to make several trials before the desired result is obtained, When the required penetration is reached, the residue left from evaporation is weighed and its per cent of the original sample taken is computed.

29. TEST FOR PENETRATION OF BITUMINOUS MATERIALS.

(A. S. T. M. Standard Method, Serial Designation: D 5–16.)

I. DEFINITION.

(1) Penetration is defined as the consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time, and temperature. Where the conditions of test are not specifically mentioned, the load, time, and temperature are understood to be 100 grams, 5 seconds, 25° C (77° F.), respectively, and the units of penetration to indicate hundredths of a centimeter.

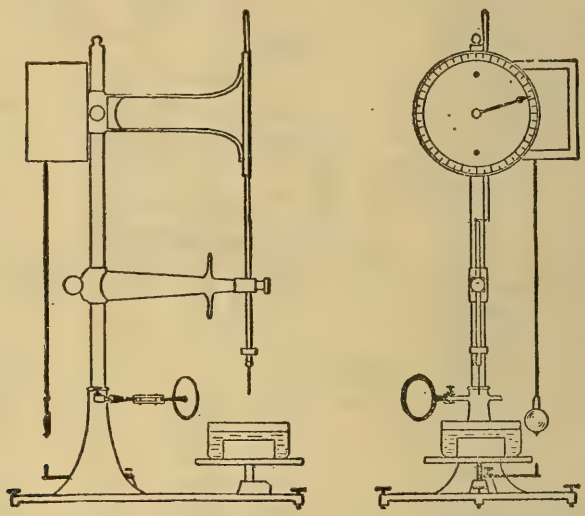


FIG. 24.—New York Testing Laboratory penetrometer.

II. APPARATUS.

(2) The container for holding the material to be tested shall be a flat-bottom, cylindrical dish, 55 mm. ($2\frac{3}{16}$ inches) in diameter and 35 mm. ($1\frac{3}{8}$ inches) deep.[8] (See figs. 24 and 25.)

(3) The needle [9] for this test shall be of cylindrical steel rod 50.8 mm. (2 inches) long and having a diameter of 1.016 mm. (0.04 inch) and turned on one end to a sharp point having a taper of 6.35 mm. (one-fourth inch).

(4) The water bath shall be maintained at a temperature not varying more than 0.1° C. from 25° C. (77° F.) The volume of water shall be not less than 10 liters and the sample shall be immersed to a depth of not less than 10 cm. (4 inches) and shall be supported on a perforated shelf not less than 5 cm. (2 inches) from the bottom of the bath.

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[8] This requirement is fulfilled by the American Can Co.'s gill style ointment box, deep pattern, 3-ounce capacity.

[9] It is recommended that the Roberts No. 2 parabola needle be used until such a time as Committee D-4 of the American Society for Testing Materials are in a position to make a recommendation relative to a type of needle which may generally be obtained.

(5) Any apparatus which will allow the needle to penetrate without appreciable friction, and which is accurately calibrated to yield results in accordance with the definition of penetration will be acceptable.

(6) The transfer dish for container shall be a small dish or tray of such capacity as will insure complete immersion of the container during the test. It shall be provided with some means which will insure a firm bearing and prevent rocking of the container.

III. PREPARATION OF SAMPLE.

(7) The sample shall be completely melted at the lowest possible temperature and stirred thoroughly until it is homogeneous and free from air bubbles. It shall then be poured into the sample container to a depth of not less than 15 mm. (⅜ inch). The sample shall be protected from dust and allowed to cool in an atmosphere not lower than 18° C. (65° F.) for one hour. It shall then be placed in the water bath along with the transfer dish and allowed to remain one hour.

IV. TESTING.

(8) (*a*) In making the test the sample shall be placed in the transfer dish filled with water from the water bath of sufficient depth to completely cover the container.

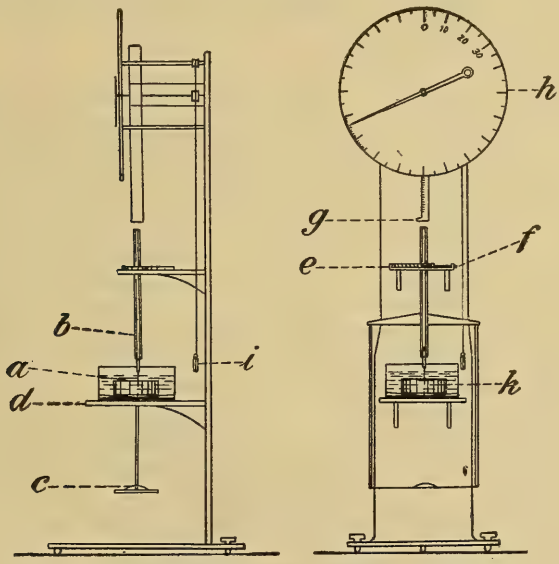

FIG. 25.—Dow penetration machine.

The transfer dish containing the sample shall then be placed upon the stand of the penetration machine. The needle, loaded with specified weight, shall be adjusted to make contact with the surface of the sample. This may be accomplished by making contact of the actual needle point with its image reflected by the surface of the sample from a properly placed source of light. Either the reading of the dial shall then be noted or the needle brought to zero. The needle is then released for the specified period of time, after which the penetration machine is adjusted to measure the distance penetrated.

At least three tests shall be made at points on the surface of the sample not less than 1 cm. (⅜ inch) from the side of the container and not less than 1 cm. (⅜ inch) apart. After each test the sample and transfer dish shall be returned to the water bath and the needle shall be carefully wiped toward its point with a clean, dry cloth to remove

all adhering bitumen. The reported penetration shall be the average of at least three tests whose values shall not differ more than four points between maximum and minimum.

(*b*) When desirable to vary the temperature, time, and weight, and in order to provide for a uniform method of reporting results when variations are made, the samples shall be melted and cooled in air as above directed. They shall then be immersed in water or brine, as the case may require, for one hour at the temperature desired. The following combinations are suggested:

At 0° C. (32° F.), 200-gram weight, 60 seconds.
At 46.1° C. (115° F.), 50-gram weight, 5 seconds.

30. DETERMINATION OF DUCTILITY OF BITUMINOUS MATERIALS.

(Method described in Trans. A. S. C. E., vol. 82, 1918, p. 1460.)

A briquette of the material to be tested shall be formed by pouring the molten material into a briquette mold. The dimensions of the briquette shall be 1 cm. (0.394 inch) in thickness throughout its entire length; distance between the clips or end pieces, 3 cm. (1.181 inches); width of asphalt cement section at mouth of clips, 2 cm. (0.787 inch); width at minimum cross section, half way between clips, 1 cm. (0.394 inch). The centerpieces are removable, the briquette mold being held together during molding with a clamp or wire.

The molding of the briquette shall be done as follows: The two center sections shall be well amalgamated to prevent the asphalt cement from adhering to them, and the briquette mold shall then be placed on a freshly amalgamated brass plate. The asphalt cement to be tested shall be poured into the mold while in a molten state, a slight excess being added to allow for shrinkage on cooling. When the asphalt cement in the mold is nearly cool, the briquette shall be cut off level, with a warm knife or spatula. When it is thoroughly cooled to the temperature at which it is desired to make the test, the clamp and the two sidepieces are removed, leaving the briquette of asphalt cement held at each end by the ends of the mold, which now play the part of clips. The briquette shall be kept in water for 30 minutes at 4° C. (39° F.) or 25° C. (77° F.) before testing, dependent on the temperature at which the ductility is desired. The briquette with the clips attached shall then be placed in a "ductility test machine" (fig. 26) filled with water at one of the above temperatures to a sufficient height to cover the briquette not less than 50 mm. (1.969 inches). This machine consists of a rectangular water-tight box, having a movable block working on a worm gear from left to right. The left clip is held rigid by placing its ring over a short metal peg provided for this purpose; the right clip is placed over a similar rigid peg on the movable block. The movable block is provided with a pointer which moves along a centimeter scale. Before starting the test, the centimeter scale is adjusted to the pointer at zero. Power is then applied by the worm-gear pulling from left to right at the uniform rate of 5 cm. (1.969 inches) per minute.

The distance, in centimeters, registered by the pointer on the scale at the time of rupture of the thread of asphalt cement shall be taken as the ductility of the asphalt cement.

31. STANDARD METHOD FOR THE DISTILLATION OF TAR AND TAR PRODUCTS.

(A. S. T. M. Standard Method, Serial Designation: D 20-18.)

(1) The sample as received shall be thoroughly stirred and agitated, warming, if necessary, to insure a complete mixture before the portion for analysis is removed.

(2) If the presence of water is suspected or known the material shall be dehydrated before distillation. About 500 c. c. of the material are placed in an 800-c. c. copper still provided with a distilling head connected with a water-cooled condenser (see

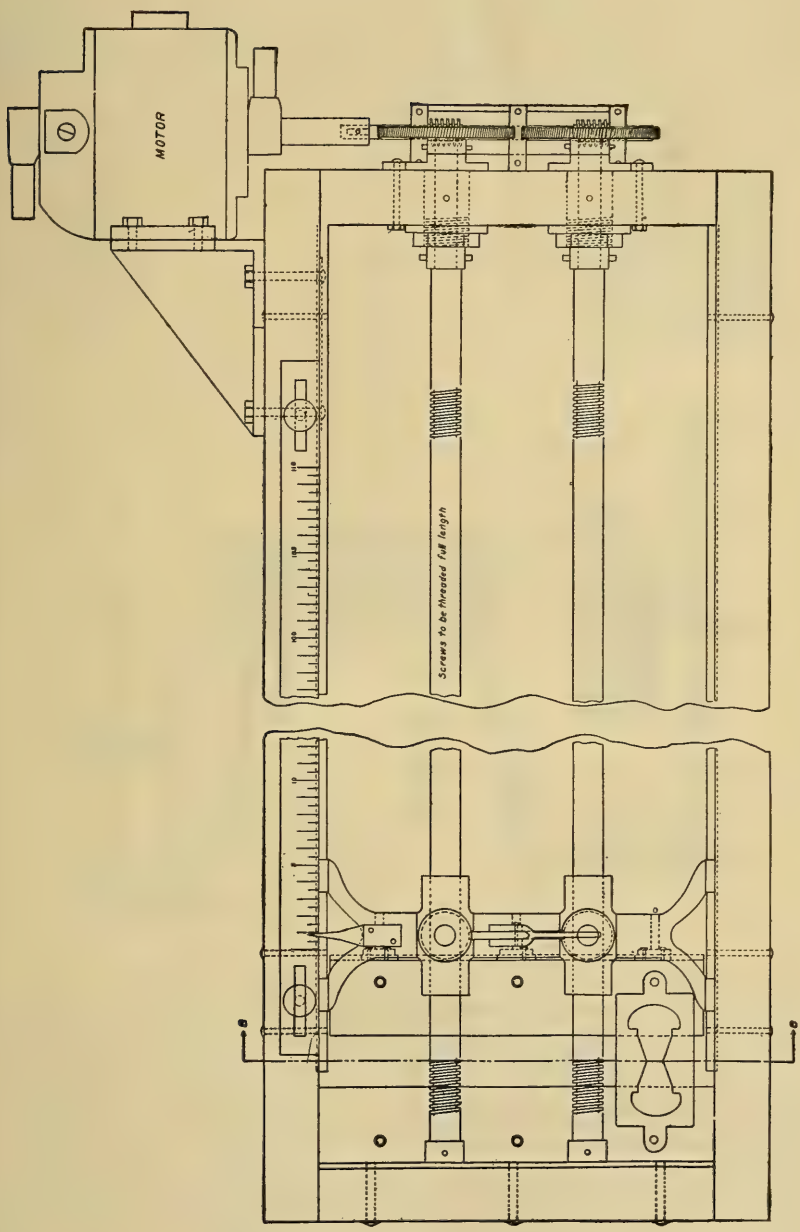

FIG. 26.—Machine for ductility test.

fig. 27). A ring burner is used, starting with a small flame at the top of the still and gradually lowering it, if necessary, until all the water has been driven off. The distillate is collected in a 200-c. c. separatory funnel with the tube cut off close to the stopcock. When all the water has been driven over and the distillate has settled out the water is drawn off and the oils returned to the residue in the still. The contents of the still shall have cooled to below 100° C. before the oils are returned, and they shall be well stirred and mixed with the residue.

(3) The apparatus shall consist of the following standard parts (see fig. 28):

(*a*) *Flask*.—The distillation flask shall be a 250-c. c. Engler distilling flask, having the following dimensions:

Diameter of bulb	8.0 cm.
Length of neck	15.0 cm.
Diameter of neck	1.7 cm.
Surface of material to lower side of tubulature	11.0 cm.
Length of tubulature	15.0 cm.
Diameter of tubulature	0.9 cm.
Angle of tubulature	75 deg.

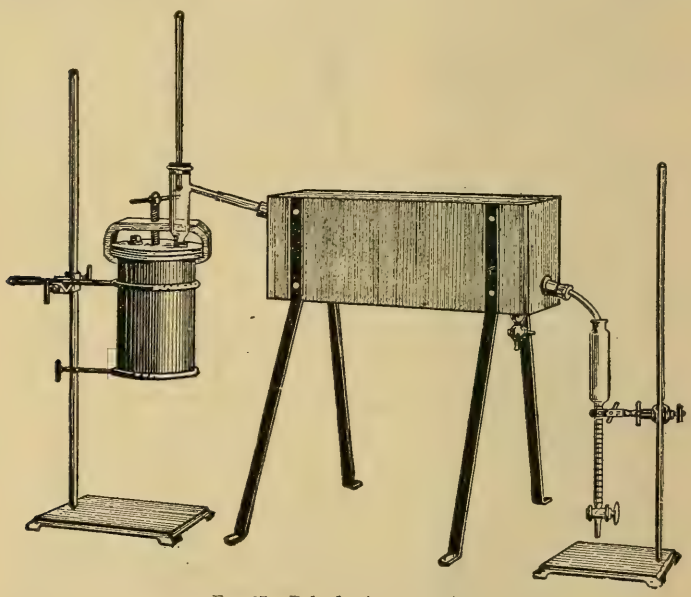

FIG. 27.—Dehydrating apparatus.

A variation of 3 per cent from the above measurements will be allowed.

(*b*) *Thermometer*.—The thermometer shall conform to the following requirements: It shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A. S. T. M. Distillation."

The thermometer shall be graduated from 0° to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

	Mm.
Total length, maximum	385
Diameter of stem (permissible variation 0.5 mm.)	7
Diameter of bulb, minimum (shall not exceed diameter of stem)	5
Length of bulb (permissible variation 2.5 mm.)	12.5
Distance from 0° to bottom of bulb (permissible variation 2.5 mm.)	30
Distance from 0° to 400° (permissible variation 10 mm.)	295

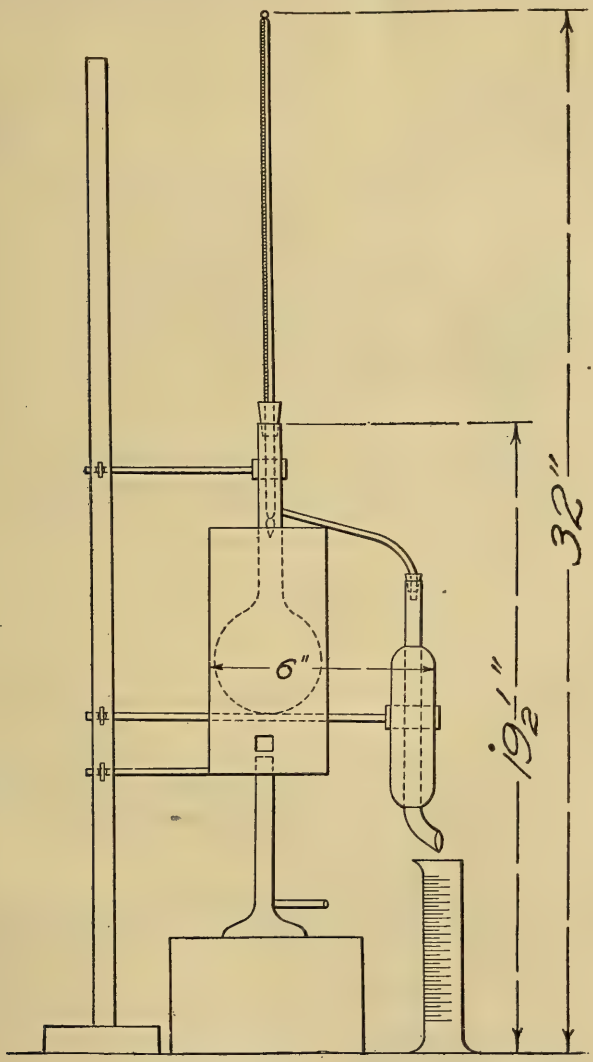

FIG. 28.—Distillation apparatus with vertical condenser.

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error shall not exceed the following:

	°C.
From 0° to 200° C	0.5
From 200° to 300° C	1.0
From 300° to 375° C	1.5

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure, at the time of test, and plunged into free flow of steam, the meniscus shall pass the point 10° C. below the boiling point of water in not more than 6 seconds.

The thermometer shall be set up as for the distillation test, using water, naphthalene and benzophenone as distilling liquids. The correctness of the thermometer shall be checked at 0° and 100° C. after each third distillation until seasoned.

(*c*) *Condenser.*—The condenser tube shall have the following dimensions:

	Mm.
Adapter	70
Length of straight tube	185
Width of tube	12 to 15
Width of adapter end of tube	20 to 25

(*d*) *Stands.*—Two iron stands shall be provided, one with a universal clamp for holding the condenser, and one with a light grip arm with a cork-lined clamp for holding the flask.

(*e*) *Burner and shield.*—A Bunsen burner shall be provided, with a tin shield 20 cm. long by 9 cm. in diameter. The shield shall have a small hole for observing the flame.

(*f*) *Cylinders.*—The cylinders used in collecting the distillate shall have a capacity of 25 c. c., and shall be graduated in 0.1 c. c.

(4) The apparatus shall be set up as shown in figure 28, the thermometer being placed so that the top of the bulb is opposite the middle of the tubulature. All connections should be tight.

(5) One hundred cubic centimeters of the dehydrated material to be tested shall be placed in a tared flask and weighed. After adjusting the thermometer, shield, condenser, etc., the distillation is commenced, the rate being so regulated that 1 c. c. passes over every minute. The receiver is changed as the mercury column just passes the fractionating point.

The following fractions should be reported:

Start of distillation to 110° C.
110 to 170° C.
170 to 235° C.
235 to 270° C.
270 to 300° C.
Residue.

To determine the amount of residue, the flask is weighed again when distillation is complete. During the distillation the condenser tube shall be warmed when necessary to prevent the deposition of any sublimate. The percentages of fractions should be reported both by weight and by volume.

32. STANDARD METHOD FOR DETERMINATION OF SOFTENING POINT OF BITUMINOUS MATERIALS OTHER THAN TAR PRODUCTS (RING-AND-BALL METHOD).

(A. S. T. M. Standard Method, Serial Designation, D 36–19.)

NOTE.—It was recommended by the conference that this method be followed for both asphaltic and tar products.

(1) The softening of bituminous materials generally takes place at no definite moment or temperature. As the temperature rises, they gradually and imperceptibly change from a brittle or exceedingly thick and slow flowing material to a softer and less viscous liquid. For this reason, the determination of the softening point must

be made by a fixed, arbitrary, and closely defined method if the results obtained are to be comparable.

I. APPARATUS.

(2) The apparatus shall consist of the following:

(*a*) A brass ring 15.875 mm. ($\frac{5}{8}$ inch) in inside diameter and 6.35 mm. ($\frac{1}{4}$ inch) deep; thickness of wall, 2.38 mm. ($\frac{3}{32}$ inch) permissible variation on inside diameter and thickness of ring, 0.25 mm. (0.01 inch). This ring shall be attached in a con-

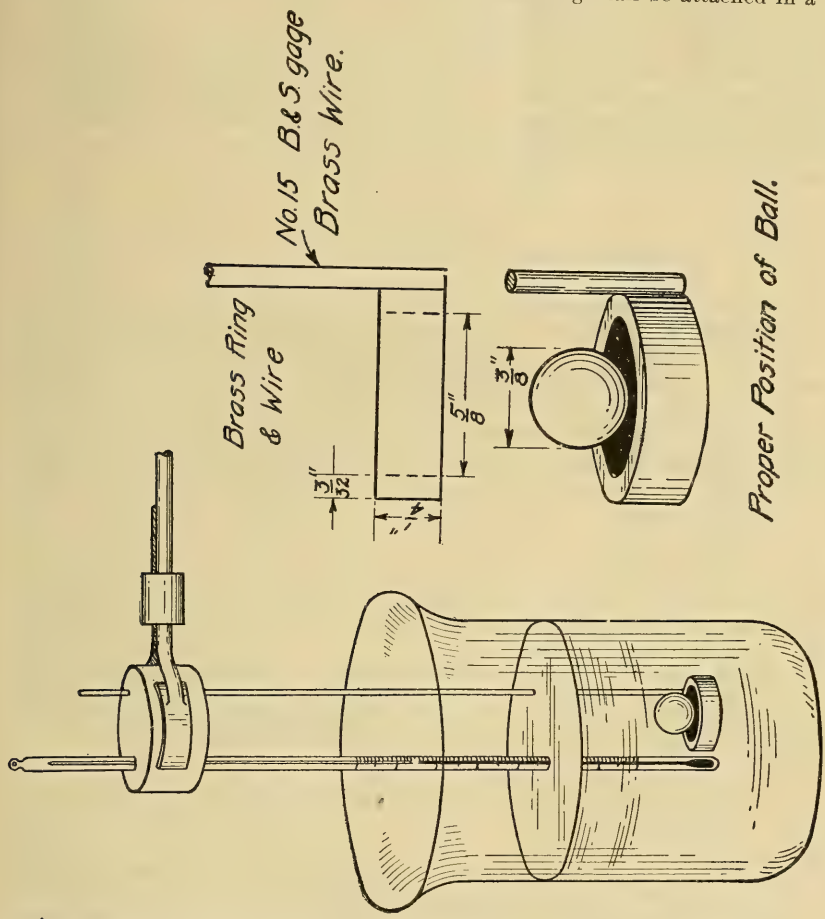

FIG. 29.—Details and assembly of apparatus for determining softening point, ring-and-ball method.

venient manner to a No. 15 B. & S. gauge brass wire (diameter 1.79 mm.=0.0703 inch). (See fig. 29.)

(*b*) A steel ball 9.53 mm. ($\frac{3}{8}$ inch) in diameter weighing between 3.45 and 3.55 grams.

(*c*) A glass vessel, capable of being heated, not less than 8.5 cm. (3.34 inch) in diameter by 10.5 cm. (4.13 inch) deep. (A 600 c. c. beaker, Griffin low form, meets this requirement.)

(*d*) A thermometer which shall conform to the following specifications:

Total length	370 to 400 mm. (14.57 to 15.75 inches).
Diameter	6.5 to 7.5 mm. (0.256 to 0.295 inch).
Bulb length	not over 14 mm. (not over 0.55 inch).
Bulb diameter	4.5 to 5.5 mm. (0.177 to 0.215 inch).

The scale shall be engraved upon the stem of the thermometer, shall be clear cut and distinct, and shall run from 0° to 80° C. (32° to 176° F.) in $\frac{1}{5}$° centigrade divisions. It shall commence not less than 7.5 cm. (2.95 inches) above the bottom of the bulb. The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and be so annealed as not to change its readings under conditions of use. It shall be correct to 0.25° C. (0.45° F.) as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the United States Bureau of Standards.

II. PREPARATION OF SAMPLE.

(3) The sample shall be melted and stirred thoroughly, avoiding incorporating air bubbles in the mass, and then poured into the ring so as to leave an excess on cooling. The ring, while being filled, should rest on a brass plate which has been amalgamated to prevent the bituminous material from adhering to it. After cooling the excess material shall be cut off cleanly with a slightly heated knife.

III. TESTING.

(A) Bituminous Materials Having Softening Points 80° C. (176° F.) or Below.

(4) Assemble the apparatus as shown in figure 29. Fill the glass vessel to a depth of substantially 8.25 cm. (3.25 inches) with freshly boiled, distilled water at 5° C. (41° F.). Place the ball in the center of the upper surface of the bitumen in the ring and suspend it in the water so that the lower surface of the filled ring is exactly 2.54 cm. (1 inch) above the bottom of the glass vessel and its upper surface is 5.08 cm. (2 inches) below the surface of the water. Allow it to remain in the water for 15 minutes before applying heat. Suspend the thermometer so that the bottom of the bulb is level with the bottom of the ring and within 0.635 cm. ($\frac{1}{4}$ inch), but not touching, the ring.

(5) Apply the heat in such a manner that the temperature of the water is raised 5° C. (9° F.) each minute.

(6) The temperature recorded by the thermometer at the instant the bituminous material touches the bottom of the glass vessel shall be reported as the softening point.

(7) The rate of rise of temperature shall be uniform and shall not be averaged over the period of the test. The maximum permissible variation for any minute period after the first three shall be 0.5° C. (0.9° F.). All tests in which the rate of rise in temperature exceeds these limits shall be rejected.

(B) Bituminous Materials Having Softening Points Above 80° C. (176° F.).

(8) Use the same method as given under (A) except that glycerine shall be used instead of water and that the thermometer shall conform to the following specifications:

Total length	370 to 400 mm. (14.57 to 15.75 in.)
Diameter of stem	6.5 to 7.5 mm. (0.256 to 0.295 in.)
Bulb length, not over	14 mm. (not over 0.55 in.)
Bulb diameter	4.5 to 5.5 mm. (0.177 to 0.217 in.)

The graduations shall be from 30° to 160° C. in $\frac{1}{2}$° C. and shall be clear cut and distinct. The 30° mark shall be at least 75 mm. above the bottom of the bulb. The length between the 30° mark and the 160° mark shall be between 230 mm. and 275 mm.

The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and so annealed as not to change its readings under conditions of use. It shall be correct to 0.25° C. as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the Bureau of Standards.

IV. ACCURACY.

(9) The limit of accuracy of the test is 0.5° C. (0.9° F.).

V. PRECAUTIONS.

(10) The use of freshly boiled distilled water is essential, as otherwise air bubbles may form on the specimen and affect the accuracy of the results. Rigid adherence to the prescribed rate of heating is absolutely essential in order to secure accuracy of results.

A sheet of paper placed on the bottom of the glass vessel and conveniently weighted will prevent the bituminous material from sticking to the glass vessel, thereby saving considerable time and trouble in cleaning.

33. METHOD FOR EXAMINATION OF BITUMINOUS MIXTURES.

A. CENTRIFUGAL METHOD.

The extractor shown in figure 30 was designed upon lines suggested by an examination of machines in use by A. E. Schutte and C. N. Forrest.[10] It consists of a one-fifth horsepower, 1,100 revolutions per minute vertical-shaft electric motor, *a*, with the shaft projecting into the cylindrical copper box *b*, the bottom of which is so inclined as to drain the spout *c*. A three-sixteenths-inch circular brass plate 9½ inches in diameter is shown in *d*, and upon this rests the sheet-iron bowl *e*, which is 8½ inches in diameter by 2⅝ inches high, and has a 2-inch circular hole in the top. Fastened to the inner side of the bowl is the brass cup *f*, having a circle of one-eighth-inch holes for the admission of the solvent, and terminating in the hollow axle, which fits snugly through a hole at the center of the brass plate. The bowl may be drawn firmly against a felt-paper ring *g*, three-fourths inch wide, by means of the 2½-inch milled nut *h*, for which the hollow axle is threaded for a distance of three-fourths inch directly below the upper surface of the plate. The axle fits snugly over the shaft of the motor, to which it is locked by a slot and cross pin, *i*.

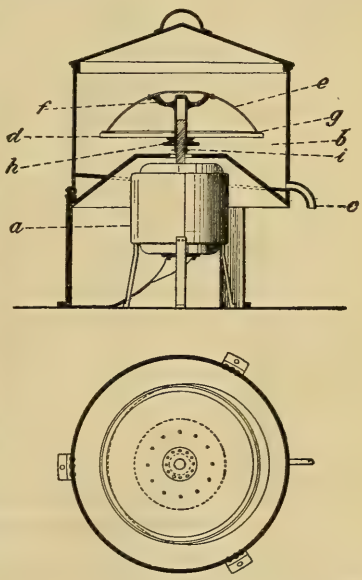

FIG. 30.—Centrifuge extractor. (Reeve type.)

The aggregate is prepared for analysis by heating it in an enamel-ware pan on the hot plate until it is sufficiently soft to be thoroughly disintegrated by means of a large spoon. Care must be taken, however, that the individual particles are not crushed. If a section of pavement is under examination, a piece weighing somewhat over 1 kilogram may be cut off with hammer and chisel. The disintegrated aggregate is then allowed to cool, after which a sufficient amount is taken to yield on extraction from 50 to 60 grams of bitumen. It is placed in the iron bowl and a ring three-fourths of an inch wide, cut from the felt paper, is fitted on the rim, after which the brass plate is placed in position and drawn down tightly by means of the milled nut. If the bitumen is to be recovered and examined, the felt ring should be previously treated in the empty extractor with a couple of charges of carbon disulphide in order to remove any small

[10] Any extractor of similar design may be used.

amount of grease or resin that may be present, although a proper grade of felt should be practically free from such products. The bowl is now placed on the motor shaft and the slot and pin are carefully locked. An empty bottle is placed under the spout and 150 c.c. of carbon disuphide (carbon tetrachloride, benzole, or chloroform may also be used as solvents) is poured into the bowl through the small holes. The cover is put on the copper box and, after allowing the material to digest for a few minutes, the motor is started slowly at first in order to permit the aggregate to distribute uniformly. The speed should then be increased sufficiently by means of the regulator to cause the dissolved bitumen to flow from the spout in a thin stream. When the first charge has drained, the motor is stopped and a fresh portion of disulphide is added. This operation is repeated from four to six times with 150 c.c. of disulphide. With a little experience the operator can soon gauge exactly what treatment is necessary for any given material. When the last addition of solvent has drained off, the bowl is removed and placed with the brass plate uppermost on a sheet of manila paper. The brass plate and felt ring are carefully laid aside on the paper and, when the aggregate is thoroughly dry, it can be brushed on a pan of the rough balance and weighed. The difference between this weight and the original weight taken shows the amount of bitumen extracted. The aggregate may then be tested as occasion requires.

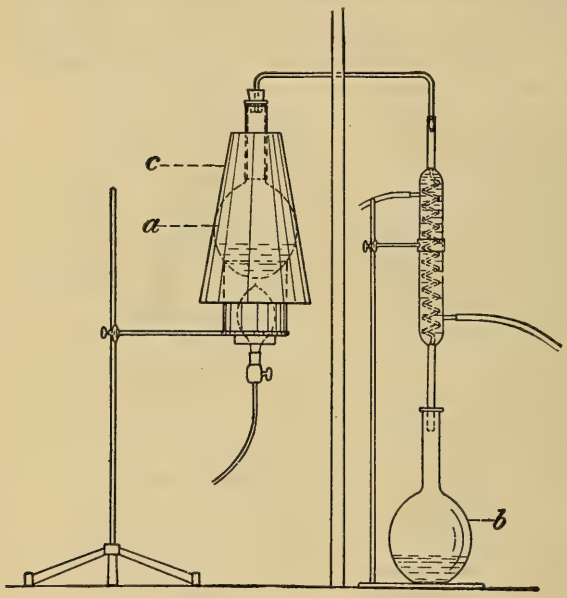

FIG. 31.—Recovery apparatus.

When it is desired to recover and examine the bitumen, the apparatus shown in figure 31 will be found convenient and fairly safe for the distillation and recovery of such inflammable solvents as carbon disulphide. In the laboratory of the Bureau of Public Roads this apparatus is arranged so that the glass tubing passes through a stone partition between two sections of a small hood, thus keeping the distilling and receiving apparatus entirely separated.

The solution of bitumen should be allowed to stand overnight in order to permit the settling of any fine mineral matter that is sometimes carried through the felt ring in the extractor. The solution is then decanted into the flask *a*, and the solvent is driven off by means of heat from an incandescent lamp until the residue is of a thick sirupy consistency. Meanwhile the solvent is condensed and recovered in the flask *b*. The residue is poured into an 11-cm. porcelain evaporating dish and evaporated on a steam bath. The most scrupulous care must be taken at all times that no flames are in its immediate vicinity. Evaporation is carried on at a gentle heat, with continual stirring, until foaming practically ceases. It is advisable to have a large watch glass at hand to smother the flames quickly should the material ignite. As the foaming subsides, the heat of the steam bath may be gradually raised, and evaporation is continued until the bubbles beaten or stirred to the surface of the bitumen fail to give a blue flame or odor of sulphur dioxide when ignited by a small gas jet.

The dish of bitumen should then be set in a hot-air oven maintained at 105° C. for about an hour, after which it is allowed to cool. Its general character is noted and any tests for bitumens that are necessary are then made upon it.

The difference between the final aggregate and the original amount taken gives the amount of bitumen extracted, which is subject to correction, dependent on the amount of ash determined from the washings.

Ash correction shall be made in the following manner: The total solution of bitumen, well stirred, is rapidly measured and an aliquot portion taken, usually 100 c. c., and poured into a previously weighed suitable flat-bottom dish, preferably quartz. The solvent is evaporated over a very low flame and the residual coke is then ignited with a burner capable of furnishing high temperature, such as a Meker. (Caution: When an inflammable solvent is used evaporation should be conducted on a steam bath and care should be taken that no flames are in the immediate vicinity.) The dish and contents are then cooled in a desiccator and the percentage of ash calculated.

B. HOT EXTRACTION METHOD.

The New York Testing Laboratory extractor consists of a large brass cylinder, through the bottom of which projects a 16-candlepower incandescent carbon-filament bulb to supply heat to the extraction apparatus proper, which is held in the upper portion of the cylinder. This apparatus is composed of a cylindrical brass vessel for holding the solvent, a cylindrical wire basket made of 80-mesh wire cloth, suspended in the cylinder, and an inverted conical condenser which serves as a top.

The aggregate is prepared for analysis by heating it in a tin dish on the hot plate until it is sufficiently soft to be disintegrated by means of a large spoon. The disintegrated aggregate is then allowed to cool. Five hundred grams of aggregates containing particles larger than one-half inch in diameter and 300 grams of aggregates with all particles smaller than one-half inch are then closely packed in the wire basket and covered with a disk or wad of absorbent cotton or felt. From 175 to 200 c. c. of carbon disulphide are next placed in the inside vessel, in which the wire basket should be suspended. The top is then placed in position and cooling water circulated through it. Heat is applied by means of the electric-light bulb. The solvent is boiled in the lower part of the extractor and condenses on the under surface of the top, from which it drips upon the wad of absorbent cotton and then percolates through the sample. A complete extraction may be made in three hours. At the end of this time the apparatus is allowed to cool and the basket containing the extracted aggregate carefully removed. After thoroughly drying, the aggregate is placed upon a pan of the rough balance and weighed. The difference between this weight and the original weight taken shows the amount of bitumen extracted which is calculated upon a percentage basis of the original. This figure should be corrected for fine mineral matter which passes through the meshes of the wire basket as follows: The solution of extracted bitumen is thoroughly agitated and measured in a glass graduate. Five or ten cubic centimeters are then poured into a weighed platinum crucible or dish, burned, and ignited to ash. The amount of mineral matter in the entire solution may then be calculated from the amount of ash produced from that portion ignited. The total percentage of such ash is then deducted from the percentage of bitumen already calculated in order to obtain the true percentage of bitumen. The amount of this correction will ordinarily vary from 0.1 per cent in uniformly coarse aggregates to 1 or 2 per cent in the analysis of aggregates containing a considerable amount of very fine mineral matter.

SUGGESTED METHOD FOR EXAMINATION OF BITUMINOUS MORTARS.

Bituminous mortars may be extracted by the use of bronze tubes which are capable of being whirled in the type of centrifuge similar to the Babcock milk tests. This method is based on decantation of the supernatant solvent. The difference between

the final aggregate and the original amount taken gives the amount of bitumen extracted which is subject to correction of the amount of ash determined from the washings. Ash correction to be made as given under A.

34. DETERMINATION OF WATER IN BITUMINOUS MATERIALS.

The apparatus consists of a copper still, 6 by 3½ inches; a ring burner to fit the still; connecting tube; condenser trough; condenser tube; separatory funnel; and a thermometer, 0°–250° C.

In the case of coal-tar material, 50 c. c. of coal tar naphtha or light oil shall be measured into a 250 c. c. graduated cylinder, and 200 c. c. of the material to be tested shall be added. In the case of petroleum products, petroleum naphtha may be used. The contents shall be transferred to the copper still and the cylinder shall be washed with 100 to 150 c. c. more of naphtha, and the washings added to the contents of the still. The lid and clamp shall be attached, using a paper gasket, and the apparatus set up as shown in figure 27. The condenser trough should be filled with water. Heat should be applied by means of the ring burner and distillation, continued, until the vapor temperature has reached 205° C. (401° F.). The distillate shall be collected in the separatory funnel, in which 15 to 20 c. c. of benzol or naphtha have been pre-

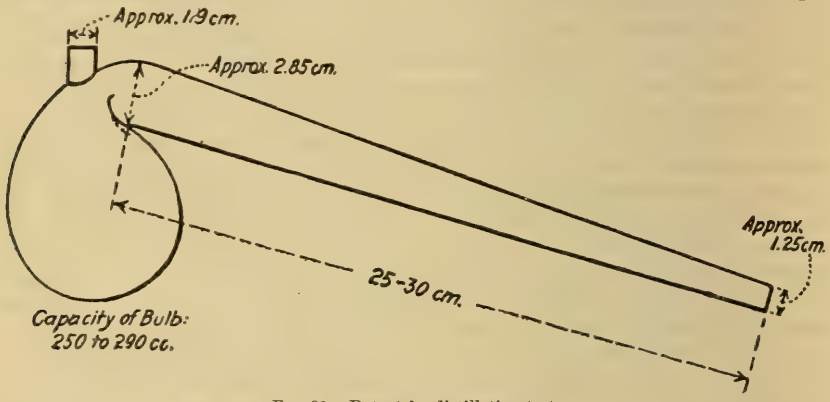

FIG. 32.—Retort for distillation test.

viously placed. This effects a clean separation of the water and oil. The reading shall be made after twirling the funnel and allowing to settle for a few minutes. The percentage shall be figured by volume.

When fresh supplies of naphtha or light oil are obtained they shall be tested to determine freedom from water.

It is recommended that further investigation be made on this method by using a water-saturated solution of naphtha. This criticism has been made on the method due to the fact that naphtha possibly possesses an affinity for water.

35. TESTS OF PREMOLDED JOINT FILLERS.

The bituminous material before manufacture into the premolded joint fillers should be subjected to the tests as for poured expansion joint fillers.

36. TESTS FOR EMULSIONS.

The essential tests on emulsions are per cent of water and quality of bitumen.

The percentage of water may be obtained by the methods of water determinations in test No. 34 without the addition of naphtha or benzol. The emulsion can be broken

down by the addition of a 10 per cent solution of calcium chloride. The separated bituminous material is then kneaded by hand to separate all contained water and then subjected to the usual quality tests.

37. DETERMINATION OF PARAFFIN SCALE.

It is recommended that the paraffin scale determination be omitted on account of difficulty encountered in obtaining dependable results due to the inaccuracy of any methods which have heretofore been introduced.

38. STANDARD METHOD FOR DISTILLATION OF CREOSOTE.

(Extract from A. S. T. M. Standard Method, Serial Designation: D 38–18.)

(1) (*a*) *Retort.*—This shall be a tubulated glass retort of the form and approximate dimensions shown in figure 32, with a capacity of 250 to 290 c. c. The capacity shall

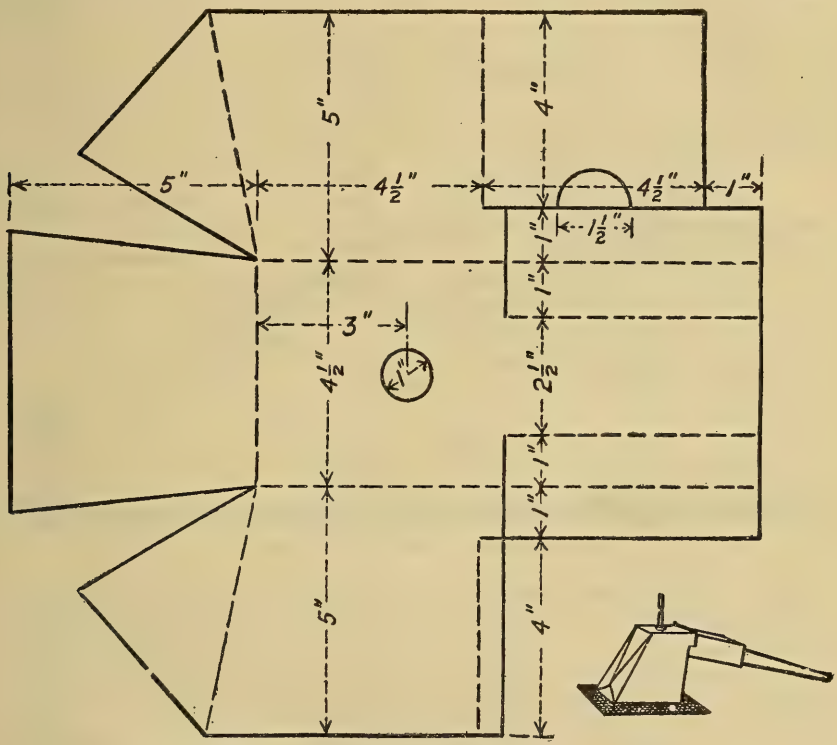

FIG. 33.—Asbestos shield.

be measured by placing the retort with the bottom of the bulb and the end of the offtake in the same horizontal plane, and pouring water into the bulb through the tubulature until it overflows the offtake. The amount remaining in the bulb shall be considered its capacity.

(*b*) *Condenser tube.*—The condenser tube shall be a suitable form of tapered glass tubing of the following dimensions:

	Mm.
Diameter of small end (permissible variation, 1.5 mm.)	12.5
Diameter of large end (permissible variation, 3 mm.)	28.5
Length (permissible variation, 4 mm.)	360.0

(*c*) *Shield.*—An asbestos shield of the form and approximate dimensions shown in figure 33 shall be used to protect the retort from air currents and to prevent radiation. This may be covered with galvanized iron, as such an arrangement is more convenient and more permanent.

(*d*) *Receivers.*—Erlenmeyer flasks of 50 to 100 c. c. capacity are the most convenient form.

(*e*) *Thermometer.*—The thermometer shall conform to the following requirements.

The thermometer shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of

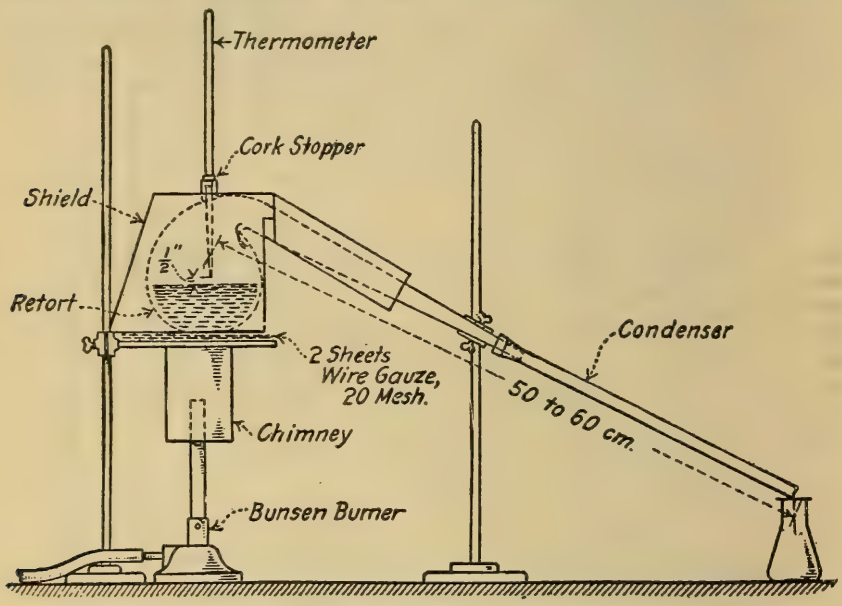

FIG. 34.—Assembled apparatus for distillation test.

the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A. S. T. M. distillation."

The thermometer shall be graduated from 0° to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

	Mm.
Total length, maximum	385
Diameter of stem (permissible variation, 0.5 mm.)	7
Diameter of bulb, minimum (shall not exceed diameter of stem)	5
Length of bulb (permissible variation, 2.5 mm.)	12.5
Distance, 0° to bottom of bulb (permissible variation, 5 mm.)	30
Distance, 0 to 400° (permissible variation, 10 mm.)	295

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error shall not exceed the following:

From 0° to 200° C.	0.5° C.
From 200° to 300° C.	1.0° C.
From 300° to 375° C.	1.5° C.

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure at the time of test and plunged into free flow of steam the meniscus shall pass the point 10° C. below the boiling point of water in not more than six seconds.

(2) The retort shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 6 inches square, as shown in figure 34. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the tubulature with the bottom of the bulb one-half inch from the surface of the oil in the retort.

The exact location of the thermometer bulb shall be determined by placing a vertical rule graduated in divisions not exceeding one-sixteenth inch back of the retort when the latter is in position for the test, and sighting the level of the liquid and the point for the bottom of the thermometer bulb. The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 24 nor less than 20 inches. The burner should be protected from drafts by a suitable shield or chimney (see fig. 34).

(3) Exactly 100 grams of oil shall be weighed into the retort, the apparatus assembled, and heat applied. The distillation shall be conducted at the rate of at least one drop and not more than two drops per second, and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. Fractions shall be collected at the following points: 210°. 235°, 270°, 315°, and 355° C. The receivers shall be changed as the mercury passes the dividing temperature for each fraction. When the temperature reaches 355°, the flame shall be removed from the retort, and any oil which has condensed in the offtake shall be drained in the 355° fraction.

The residue shall remain in the retort with the cork and the thermometer in position until no vapors are visible; it shall then be weighed. If the residue is to be further tested it shall then be poured directly into the brass collar used in the float test or into a tin box and covered and allowed to cool to air temperature. If the residue becomes so cool that it can not be poured readily from the retort, it shall be reheated by holding the bulb of the retort in hot water or steam, and not by the application of flame.

For weighing the receivers and fractions, a balance accurate to at least 0.05 grams shall be used.

During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

When any measurable amount of water is present in the distillate it shall be separated as nearly as possible and reported separately, all results being calculated on a basis of dry oil. When more than 2 per cent of water is present, water-free oil shall be obtained by separately distilling a larger quantity of oil, returning to the oil any oil carried over with the water, and using dried oil for the final distillation.

TENTATIVE TESTS.

39. PROPOSED SOUNDNESS TEST FOR COARSE AGGREGATE.

Immerse 10 small pieces of the rock in a saturated solution of sodium sulphate (Na_2SO_4), for 20 hours, after which place for four hours in a drying oven maintained at 100° C. Repeat the treatment five times. The condition of the rock as to soundness is noted at the end of the test.

Samples which exhibit marked checking, cracking or disintegration shall be considered to have failed in this test.

40. TENTATIVE TEST FOR ABSORPTION OF CONCRETE.

It is recommended that the method of making the absorption test prescribed for cement drain tile in the Standard Specification for Drain Tile, American Society for Testing Materials, Serial Designation C 4–16, be employed for making the absorption test of concrete until a different method is developed.

41. PROPOSED TEST FOR PERCENTAGE OF SHALE IN GRAVEL.

It is suggested that for the separation of shale and other pieces having low specific gravity from concrete aggregates, a solution of zinc chloride ($ZnCl_2$) or some other satisfactory liquid having a specific gravity of approximately 1.95 be used. A sample of the pebbles should be first dried to constant weight at not over 110° C., then placed in a container partially filled with the solution. Agitate for five minutes, skim off the lighter materials and then pour the solution through a sieve which will retain the pebbles. Repeat the operation until the entire sample has been separated. Dry to constant weight, measure the volume of retained material and compute the percentage by volume of shale or other soft material.

42. PROPOSED MODIFICATION OF THE ABRASION TEST FOR BROKEN STONE AND SLAG.

It is recommended that in order to secure data for a revision of the standard abrasion test for stone, abrasion tests on broken stone and slag be run parallel with the regular test (described on page 3) but with a charge of stone made up in the manner prescribed for the charge of gravel for the abrasion test. The purpose is to determine whether it is possible to secure consistent results with a charge for the abrasion test made up from the product of the crusher as it is delivered to the job.

43. PROPOSED ABRASION TEST FOR FINE AGGREGATE.

The following is a tentative method for determining the resistance of the fine aggregate to abrasion. The fine aggregate is washed and dried at a temperature not exceeding 110° C. All material retained on the $\frac{1}{4}$-inch sieve, and all material passing a standard 50-mesh sieve is discarded. Five hundred grams of the portion passing a $\frac{1}{4}$-inch screen and retained on a 50-mesh sieve are placed in a Deval abrasion cylinder with a charge of 250 grams of $\frac{9}{16}$-inch commercial steel bearing balls which shall weigh within 1 per cent of the required 250 grams. The charge in the Deval abrasion cylinder is rotated for 2,000 revolutions at the rate of 33 revolutions per minute. The sample of sand is removed and sieved over a 100-mesh sieve. The sample is prefer-

ably divided into three portions for sieving, the sieving being completed over a sheet of white paper, and is continued until practically no dust passes the sieve when shaking for one minute. The portion retained on the 100-mesh sieve is weighed. Five hundred grams minus the weight of the samples retained on the 100-mesh after abrasion is taken as the loss from abrasion. This weight divided by 5 gives the percentage of wear.

44. PROPOSED FIELD METHODS OF MAKING SIEVE ANALYSIS.

Either volumetric or gravimetric methods may be used on a sample of not less than 500 grams in the volumetric or 200 grams in the gravimetric test. The following methods for making these tests are suggested:

A. VOLUMETRIC METHOD.

Briefly described, the apparatus for this test consists of an outside cylindrical container with telescopic cover, two nests of semicylindrical screens and sieves fitting into the outside cylinder and containing a smaller cylinder with telescopic cover. This small cylinder contains in turn a 10-inch rule having $\frac{1}{10}$-inch divisions and a 200 c. c. graduated cylinder. The entire outfit is very compact, measuring about 14 inches in length and 5 inches in diameter.

Both the outer and inner cylinders are exactly 10 inches in inside depth, the telescopic covers being made to fit the contents of each cylinder. As used at present, there are in each outfit five screens having circular openings $1\frac{1}{2}$-inch, 1-inch, $\frac{3}{4}$-inch, $\frac{1}{2}$-inch, and $\frac{1}{4}$-inch in diameter, respectively, and three sieves of standard 10-mesh, 20-mesh, and 50-mesh, respectively; also three rings of 3-inch, $2\frac{1}{2}$-inch, and 2-inch diameter, respectively, fitting in the cover of the container.

The large cylinder is used when making a screen analysis of a coarse aggregate, while the small cylinder is used in determining the gradation of sand or other fine aggregate. The cylinder is filled with the material to be examined, which is then screened through the screen, or sieve, selected. The portion passing the screen, or sieve, is returned to the cylinder and the height of the material determined, each 0.1 inch corresponding to 1 per cent of the original volume. The portion retained on the screen, or sieve, is determined in the same manner. The percentage passing plus the percentage retained when obtained in this manner add up to more than 100 per cent of the original volume, and if the true percentage passing each screen or sieve is to be reported, the correct value is obtained by dividing the percentage passing each screen or sieve as found above by the total of the measurements obtained for material retained and material passing the screen or sieve. For example, if a gravel shows by measurement 60 per cent retained on a 1-inch screen and 50 per cent passing a 1-inch screen, the true percentage passing the 1-inch screen is—

$$\frac{50}{60+50}=\frac{50}{110}=45\tfrac{1}{2} \text{ per cent.}$$

B. GRAVIMETRIC METHOD.

The apparatus required consists of a spring balance, 200-grams capacity, graduated to tenth-gram divisions and provided with a weighing pan; a series of field sieves well graded in size from a $\frac{1}{4}$-inch screen to a standard 200-mesh sieve. The sample, selected in accordance with the method described, shall be dried in the air or by heating to not over 110° C. The sample for sieve analysis shall be selected from the dried sample by the method of quartering and shall weigh approximately 200 grams. This sample shall be passed successively through the various screens required and the total percentage passing each sieve shall be reported.

45. PROPOSED FIELD DETERMINATION OF CLAY AND SILT.

The apparatus used in this test is the same as that described under the volumetric method of making sieve analysis, test 44. Two hundred c. c. of the sand or other fine aggregate are measured in the graduated cylinder and transferred to the small cylindrical container. Water is added and the sand washed by agitation. The large mineral particles are allowed to settle and the water containing the clay and silt is poured into the large outside cylindrical container. The operation of washing with new portions of fresh water is repeated until the wash water remains clear. The water in the large container is allowed to stand over night to permit the clay and silt to settle out. The clear supernatant water is then poured off and the sediment of clay and silt remaining is transferred to the 200 c. c. graduated cylinder. Water is added to bring the contents of the graduated cylinder to 200 c. c. The volume of sediment in the cylinder is determined at the end of three hours. This volume divided by 2 gives the percentage by volume of clay and silt on a wet basis, three hours standing. This value is usually from 2½ to 4 times the value obtained when determining the clay and silt by dry weight. If we assume, therefore, that the specifications require not more than 5 per cent of clay and silt by dry weight, less than 7½ per cent by volume of clay and silt would indicate that the fine aggregate complies with the specifications, while more than 12 per cent by volume of clay and silt would indicate an excess of material removed in washing.

46. PROPOSED METHODS OF FABRICATING AND TESTING COMPRESSION FIELD SPECIMENS OF CONCRETE.

As a guide to the selection of the sample of the concrete and to the method of making compression specimens in the field see the procedure outlined in Appendix 1, in the report of Committee C–9 in the Proceedings of the A. S. T. M. vol. 17, part 1.

The essential part of the report is as follows:

Sampling the concrete.—Concrete for the test specimens should be taken immediately after it has been placed in the forms. All the material for each sample should be taken from one place. A sufficient number of samples—each large enough to make one test specimen—should be taken at different points so that the specimens made from them will give a fair average of the work. The location from which each sample is taken should be clearly noted for future reference.

In securing samples, the concrete is taken from the mass by a shovel or a similar implement and placed in a large pail or in some other receptacle for transporting to the place where the specimens are molded. Care should be taken to see that each specimen represents the total mixture of the concrete at that place.

Molding the specimen.—The pails containing the samples of concrete should be taken to the place selected for making the test pieces as quickly as possible. To offset segregation of materials during transportation, each sample should then be dumped out of the pail into a nonabsorbent water-tight receptacle and without further mixing immediately placed in the mold. Different samples should not be mixed together, but each sample should make one specimen.

(The conference recommends that a ½-inch rod 2 feet long should be used for puddling the concrete instead of the ¾-inch rod recommended by Committee C–9. The conference also recommends that the material be placed in the mold in layers 3 inches deep and each layer puddled 20 times with the rod.)

"Ramming should be avoided, but care should be taken to remove air pockets. The freshly made specimen should be struck off and troweled level with the top of the form. The specimen should preferably be capped in the field while it is in the mold so as to be ready for the testing machine. After the concrete has stiffened appreciably and before the molds are removed, neat cement or a rather stiff 1:2 mortar may be used to fill the molds level full. A piece of plate glass or machined metal plate should then be worked around on the top of the mortar until it rests on the form.

This plate should be oiled or a piece of wax paper be placed between it and the concrete. If the forms are carefully made, this will give top and bottom surfaces perpendicular to the sides of the specimens. To prevent the specimen from drying out, it should be covered or otherwise protected. If desired, the mold itself may be buried in sand while the specimen is being molded.

"At the end of 48 hours the specimens should be removed from the mold and buried in damp sand."

(It is the sentiment of the conference that oftentimes in concrete road construction it would be advisable to cure the test pieces along the side of the slab, under conditions similar to those of the pavement.)

"*Testing.*—Ten days prior to the date of test, specimens should be well packed in damp sand or wet shavings and shipped to the testing laboratory, where they should be stored either in a moist room or in damp sand until the date of the test. It is assumed that ordinarily a 28-day test will be made, although tests at 7 and 14 days will give some indications of the results to be expected at 28 days. In case 7-day tests are made, the test pieces should remain at the job as long as possible to harden, and should be shipped so as to arrive at the laboratory in time to make the test on the required date."

47. PROPOSED METHODS OF MAKING TEST SPECIMENS OF CONCRETE IN THE LABORATORY.

The conference recommends that concrete specimens shall be proportioned by volume. The measurements of the unit volumes of aggregate shall be made in accordance with the method outlined under "Weight per cubic foot of aggregate" (p. 11). Volumes required for the given quantity of concrete shall be measured by weighing the requisite amounts of each material. The weight of 1 cubic foot of cement shall be assumed to be 94 pounds. In weighing quantities of a coarse aggregate which varies considerably in size of particles, it is suggested that the aggregate be graded into different sizes and the proper proportions of each of these sizes be used.

In making specimens sufficient quantities of materials [11] to fill a single specimen mold with an excess of 10 per cent should be calculated. The dried materials should be placed on a metallic or other nonabsorbent mixing tray and thoroughly mixed to a uniform color with a square-nose trowel. The requisite amount of water for tempering the mix to proper consistency should be weighed. The dry material should be formed into a crater and about three-fourths of the estimated amount of water added. The entire batch should then be turned until of uniform composition, water being added until the required consistency has been obtained. The amount of water actually used in the mixture should be recorded.

In molding the test pieces, the form should be filled to about one-quarter of its height and thoroughly puddled with a ½-inch rod, using 20 strokes per layer.

From two to four hours after molding, compression specimens should be capped with a layer of neat cement in order that the top of the specimen may present a smooth surface for loading. The cap can be readily formed by means of a glass plate which may be worked down on the neat cement until it rests on top of the form. In order to eliminate shrinkage, the cement for capping should be mixed to a stiff paste before the concrete specimens are made. Adhesion of the concrete to the base of the mold and to the glass can be eliminated by oiling the base and by inserting a sheet of paraffined tissue paper beneath the glass. Specimens should be removed from the forms on the day after they are fabricated, marked, and stored in damp sand, or in a moist chamber until tested.

It is recommended that tests be made at 7, 28, or 90 days; the 28-day period is the most commonly used.

[11] In most cases it is preferable to use air-dry aggregate.

Compression tests.—The specimen to be used in compression tests shall be a cylinder not less than 6 inches in diameter and 12 inches high. When the diameter of the largest particle of aggregate runs over 2 inches an 8 by 16 inch cylinder is recommended.

The mold should be of metal. A suitable type of mold consists of a 12-inch length of cold-drawn steel tubing 6 inches inside diameter, split along one element, and closed by means of a circumferential band and bolt. Suitable forms can also be made from galvanized iron. Forms should be tight and should rest on level nonabsorbent bases.

At least three specimens should be made to cover any single point in a series of tests. Only one cylinder of a kind should be fabricated at one time.

In testing compression specimens the speed of the moving head of the machine shall travel approximately 0.05 inch per minute when the machine is running idle. The bearing plates of the testing machine shall be brought into direct contact with the end of the specimen, and a spherical bearing block shall be used on top of the test piece. The diameter of the bearing block shall be approximately the same as that of the specimen; the radius of the ball in the block should be not over one-half the radius of the test piece. As the testing head of the machine is brought down upon the top of the cylinder, the lower section of the adjustable block should be oscillated to and fro to insure a central bearing and to avoid pulling the cylinder to one side.

The results of the tests of individual specimens should be reported.

48. PROPOSED TRANSVERSE TESTS OF CONCRETE.

Field specimens.—A slab 30 inches long, 8 or 12 inches wide, and of a depth equal to the depth of pavement should be employed. This specimen should be molded at the edge of the pavement with its long dimension parallel to the length of the road. The forms for separating the test piece from the remainder of the road should be made of sheet metal and should be submerged about three-fourths of an inch below the finished surface of the pavement. In order to provide bearing surfaces and a uniform thickness at the center, three strips of wood 3 inches wide should be placed on the subgrade with their axes running transversely with respect to the axis of the test specimen and wide faces parallel to and equidistant from the top of the pavement. The boards should be placed near each end and at the center of the length of the test piece. Specimens should be tested over a 24-inch span and loaded at the center.

Laboratory specimens.—A specimen 12 inches wide, 8 inches deep, and 30 inches long, to be tested by center load over a 24-inch span, is suggested for laboratory fabrication. The methods of proportioning, mixing, molding, and curing of the transverse test piece should be similar to the method previously outlined.

The modulus of rupture S_r may be found from the following expression: Thus $S_r=\frac{36P}{bd^2}$ in which P is the center load in pounds and b and d the breadth and depth in inches of the slab, respectively.

49. PROPOSED TEST FOR CONSISTENCY OF CONCRETE.

For the determination of the consistency either in the field or in the laboratory the committee proposes the use of the 4 by 8 by 12 inch conical frustum, as shown in figure 35.

In making the test, the thoroughly cleaned frustum should be placed on a level nonabsorbent surface and filled with 3-inch layers of concrete. During filling, the mold should be held down by the operator placing his toes on the lip at the bottom of the mo d. As each layer of material is introduced it should be puddled by a stirring motion with a one-half-inch rod to uniformly distribute the material.

After the upper layer has been placed the top shall be struck off and the mold removed by slowly pulling it vertically upward. The height of the frustum shall be measured and the slump calculated from the difference of the height of the mold and the frustum.

In making the slump test in the laboratory or in the field it is recommended that the form be filled immediately after mixing and withdrawn three minutes after mixing has been completed.

When central mixing plants are used slump tests shall be made at the plant and at the end of the haul. At the plant the sample of concrete shall be taken after the

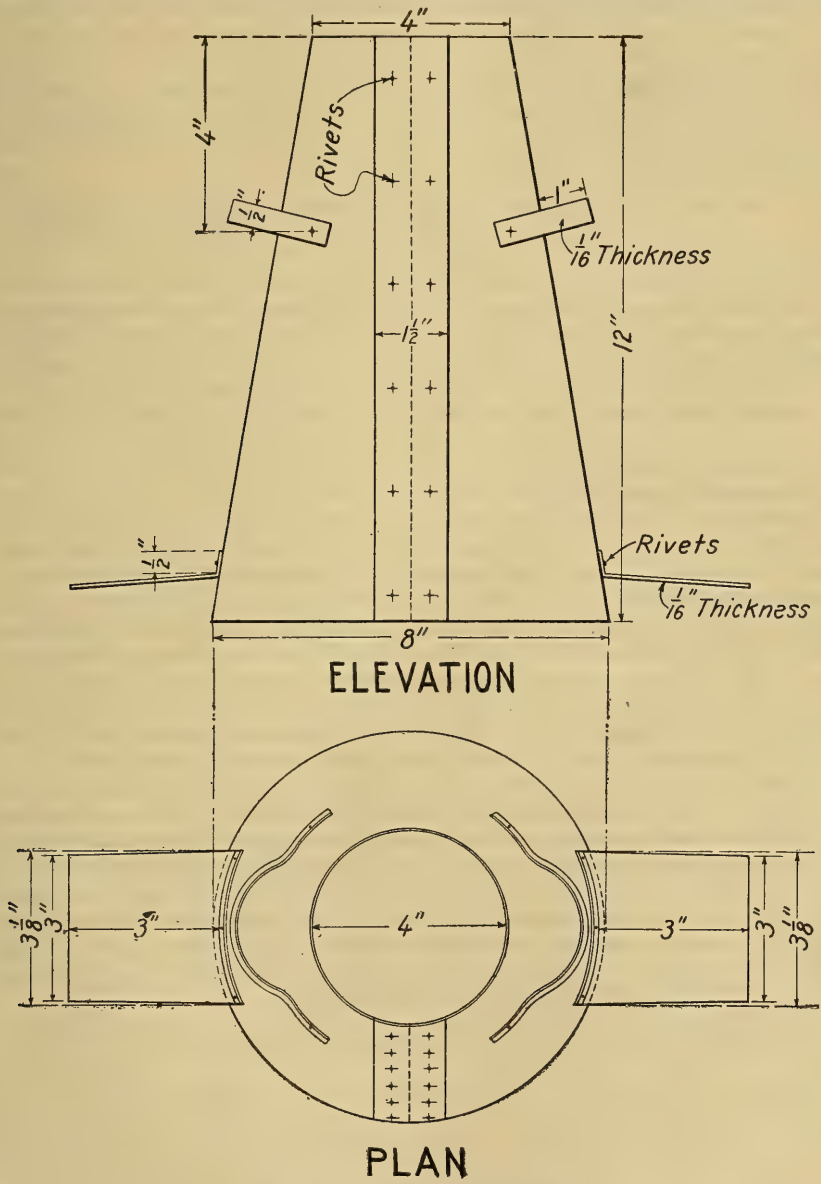

FIG. 35.—Cone for concrete slump test.

entire batch has been discharged from the mixer. At the end of the haul the slump sample shall be taken from the batch after it has been dumped on the subgrade. The slump at the points of deposition shall be suitable for the particular type of finish employed.

50. DETERMINATION OF PERCENTAGE OF PIGMENT IN PAINTS.

The per cent of pigment shall be determined by extracting a weighed amount of from 10 to 50 grams of the paint, or from 5 to 30 grams of the paste, several times with light paraffin naphtha (preferably 86° B.), using approximately 50 c. c. of fresh naphtha for each extraction, and repeating the operation until the liquid of extraction remains clear and colorless. The amount taken for analysis may be varied according to the nature of the material. The extraction and washing of the pigment shall be completed by the use of two or three portions of about 50 c. c. of ether, the pigment finally dried to constant weight at 105° C., and the per cent of pigment by weight calculated. One hundred less the per cent of pigment found shall be considered as the per cent of vehicle.

51. TESTS FOR THE AMOUNT OF SPELTER COATING ON CULVERT METAL.

The amount of spelter coating shall be determined by one of the following methods:

(*a*) *Lead acetate method.*—The solution used for making this test is prepared by dissolving 400 grams of crystallized lead acetate in 1 liter of water. When dissolved, add 4 grams of finely powdered litharge and agitate until most of it has dissolved. The solution is allowed to settle and the clear portion decanted for use.

Ordinary glass tumblers have been found very satisfactory to use in making this test, as they are the right diameter to enable the sample to be maintained in an upright position without supports.

Use several $2\frac{1}{4}$-inch by $2\frac{1}{4}$-inch pieces cut accurately to $\frac{1}{64}$ inch and weighed to three decimal places. Weigh and submerge separately, for 3 minutes, in tumblers containing solution of lead acetate. The samples are then taken out and the adherent lead, removed with a stiff brush or steel spatula. A burnishing action should be avoided, as under some conditions closely adherent lead will be plated out on the iron. Repeat the 3-minute immersions in the lead acetate solution until a bright surface is exposed. Four 3-minute immersions are usually sufficient. Wash specimens in water, dry, and weigh. The loss in grams will also be the loss in ounces per square foot.

(*b*) *Antimony hydrochloric acid method.*[12]—Use several $2\frac{1}{4}$-inch by $2\frac{1}{4}$-inch pieces, weighed to three decimal places. They are then immersed separately for one-half minute in hydrochloric acid of specific gravity 1.20 to which has been added 5 c. c. of antimony chloride solution prepared by dissolving 20 grams of antimony trioxide in 1,000 c. c. of hydrochloric acid of specific gravity 1.20. The pieces are scrubbed with a brush under running water, dried, and weighed again. About 100 c. c. of the hydrochloric acid will usually be sufficient for immersing the test pieces if a 200 c. c. beaker is used. The same portion of hydrochloric acid may be used for at least 5 test pieces. Five cubic centimeters of the antimony chloride solution, however, should be added for each sample on account of the antimony being removed from the solution by the iron. The test pieces being exactly $2\frac{1}{4}$ inches by $2\frac{1}{4}$ inches, the loss in grams will also be the loss in ounces per square foot.

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[12] This method is discussed at length in the Proceedings of A. T. M. 1915, p. 120.

RECOMMENDED STANDARD METHODS OF SAMPLING.

52. SAMPLING BROKEN STONE.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the stone is to be accepted or rejected, also from every —— cubic yards quarried, or when the quality or appearance of the stone changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—(*a*) Sampling for quality: Samples shall be taken either from the quarry or from cars as directed by the engineer, and shall be sound interior rock, representative of that which it is proposed to use. Mixed samples may be taken if deemed necessary by the engineer.

(*b*) Sampling for size: Samples of the crusher product shall be taken either at the crusher or from cars as directed by the engineer. The sample shall be mixed from runs of the crusher on different days, or if taken from cars, shall be taken from both ends and top and bottom of the car.

(4) *Amount and size of sample.*—(*a*) Sampling for quality: A sample shall weigh between 25 and 40 pounds and shall consist of pieces of rock at least 1½ inches in size and one piece at least 3 by 4 by 6 inches, free from seams and cracks, and with bedding plane marked.

(*b*) Sampling for size: A sample for size shall weigh not less than 10 pounds for materials of three-quarters inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of quarry investigations, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of rock.

Notification of sampling containing the above data shall be forwarded separately to the laboratory immediately upon taking the sample.

53. SAMPLING BROKEN SLAG.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the slag is to be accepted or rejected, also from every —— cubic yards quarried, or when the quality or appearance of the slag changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—(*a*) Sampling for quality: Samples shall be taken either from the deposit or from cars as directed by the engineer, and shall be representative of that which it is proposed to use. Mixed samples may be taken if deemed necessary by the engineer.

(*b*) Sampling for size: Samples of the crusher product shall be taken either at the crusher or from cars as directed by the engineer. The samples shall be mixed from runs of the crusher on different days, or if taken from cars, shall be taken from both ends and top and bottom of the car.

(4) *Amount and size of sample.*—(*a*) Sampling for quality: A sample shall weigh between 25 and 40 pounds and shall consist of pieces of slag at least 1¼ inches in size and one piece at least 3 by 4 by 6 inches.

(*b*) Sampling for size: A sample for size shall weigh not less than 10 pounds for material of three-quarters inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of quarry investigations, owner, quantity available, whether material from the same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of slag.

Notification of sampling containing the above data shall be forwarded separately to the laboratory immediately upon taking the sample.

The conference, recognizing that in general slag is not a uniform product, recommends that special care should be taken to get a representative sample.

54. SAMPLING STONE BLOCK.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken at least —— days before the block is to be accepted or rejected, or when the quality or appearance of the block changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—Samples shall be taken either from the quarry or from cars, as directed by the engineer. They shall be representative of the block which it is proposed to use; and no samples shall include blocks that would be rejected by a visual examination.

(4) *Amount and size of sample.*—The sample shall consist of at least 10 blocks. The bedding plane shall be marked on at least 2 blocks.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes and shall be accompanied by a card in the container, or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, whether material from same source has been previously used, where and for what purpose and with what results, initial cost of block, haul to nearest point on road, average haul to job, character of haul, and space for remarks.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

55. SAMPLING GRAVEL.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the gravel is to be accepted or rejected, also from every ——

cubic yards excavated, or when the quality or appearance of the gravel changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—(*a*) Sampling at the pit: Enough samples shall be taken to represent an average of the material. An individual sample must be taken through a full vertical section of that material which it is proposed to use at the point selected. Each sample shall be taken from a freshly exposed vertical face.

(*b*) Sampling from cars, barges, etc.: Enough samples shall be taken, as directed by the engineer, to represent average composition. Samples from cars shall be taken from both ends and from top and bottom of the car.

(4) *Amount and size of sample.*—(*a*) Sampling for quality: For screened gravel sample shall weigh 25 to 30 pounds. For bank gravel sample shall weigh 50 to 75 pounds.

(*b*) Sampling for size: A sample for size shall weigh not less than 10 pounds for materials of three-quarter-inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and, in case of pit or bank investigation, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of gravel.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

56. SAMPLING SAND.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the sand is to be accepted or rejected, also from every —— cubic yards excavated, or when the quality or appearance of the sand changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—Samples shall be taken from freshly exposed portions of the deposit as directed by the engineer. Mixed samples may be taken if deemed necessary.

In general, the number of samples shall be sufficient to cover the extreme variation of quality in that part of the deposit which is proposed to be used.

(4) *Amount and size of sample.*—Each sample, whether individual or composite, shall weigh between 10 and 15 pounds.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of source investigation, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of sand.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

57. SAMPLING SEMIGRAVEL, TOP SOIL, AND SAND-CLAY.

Samples of materials of this class shall be of two kinds: Class I, samples of the raw material taken from the natural deposit; Class II, samples of the loose material after being mixed in place on the roadbed and before consolidation.

Class I samples shall be used simply as preliminary evidence of the suitability of the aggregate, subject to admixture of one or more ingredients to adjust the composition to the limits set forth in the specifications.

The final acceptance of the material as satisfying the specifications shall be based on Class II samples.

Standard containers.—(1) A three-compartment box of pasteboard, wood, or metal, outside dimensions 5 by 10 by 10 inches; or (2) close woven bags or sacks of material which do not allow sifting out of fine particles, dimensions 6 inches wide by 12 inches long.

Labeling.—Each compartment in the box container must contain a label showing at what depth the contents were taken. The whole sample shall be accompanied by a card, securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, position within the deposit where taken, owner, quantity available, amount and character of stripping, if any, whether material from same source has been previously used, where, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of material.

When bag containers are used, one complete sample shall comprise 3 bags, each bag labeled as to depth from which the material is taken.

Each bag, or, if preferred, a larger receptacle containing the three bags, is to be labeled with the information detailed above.

How to take Class I samples.—For each 1 acre or less of area two samples must be taken, one a local sample and the other a composite sample.

The local sample is to be taken near the center of the area and is intended to represent the vertical average of the material at that point. It shall be taken in three layers, each layer —— inches thick, according to the method described as follows:

The material is to be loosened over a 3 by 3 foot area to the specified depth, usually 4 inches. The loose material is to be intermixed with a shovel and the sample for one compartment of the box container or one of the bags is to be taken therefrom.

The remaining loose material is to be shoveled out and discarded. The second layer is to be loosened to equal depth, usually 4 inches, to be intermixed as before, and a second compartment or bag is to be filled. The same procedure shall apply to the third layer and the filling of the third compartment or bag.

In exceptionally thick deposits the depth of each layer or the number of layers may be increased to cover the entire thickness of the deposit.

The composite sample is to be taken as follows: Roughly divide the area to be represented by the sample into squares not exceeding 50 feet in size. At the corners of all squares loosen a 3 by 3 foot area to a depth of ——[13] inches. Thoroughly mix the loose material. Carry an equal amount of the material from each such point to a central point and intimately mix the various samples. Not less than 200 pounds of material must be so mixed. From the center of the pile of mixed material fill a container and label for shipment.

Where the material occurs as a substratum sink no less than four 3 by 3 foot pits per acre or smaller area to intersect the material. Remove the covering, and sample the exposed bed as for a local sample described above.

How to take Class II samples.—These are the most important samples and should be taken by the engineer or competent inspector while work is in progress.

[13] A depth of 8 inches is suggested.

When the materials have been spread and intimately mixed in accordance with properly drawn clauses covering methods of construction, the engineer should fill a container at intervals of —— [14] feet, along the road, and also at such other points as his judgement may dictate, where evidence of unsatisfactory mixing is apparent.

Very prompt examination of these samples should be made in order that defects of composition may be remedied by the builder before consolidation has progressed.

58. SAMPLING BITUMINOUS MATERIALS.

GENERAL RECOMMENDATIONS.

All samples should be selected to represent as nearly as possible an average of the material, care being taken that they are not contaminated with other materials. It is recommended also that special care be taken to forward the samples in clean, suitable containers, and wherever possible all materials should be sampled at the point of manufacture, and sufficiently in advance of shipment of the material represented to allow for the testing and reporting upon the samples before shipment. When impracticable to take samples at the point of manufacture they should be taken by the engineer or inspector from the shipment immediately upon delivery.

In collecting samples, if there is any doubt of the homogeneity of the material it is recommended that individual samples be lifted as hereinafter described, and such samples should be forwarded to the laboratory, where tests should be conducted to determine the uniformity, after which a composite sample of equal parts of the individual samples may be mixed for complete tests.

Samples should be taken as frequently as neccessary to insure the uniformity of the material.

Marking samples.—Samples should be marked for identification in such manner that the identification will not be removed in transit. Notification of sampling containing this identification, together with such other information as is required or of advantage to the laboratory, should be separately forwarded to the laboratory immediately upon taking the sample.

Size of samples.—No sample should be less than 1 quart, whether for complete testing or for individual test.

Plant sampling.—Drip samples are recommended. In taking drip samples, the pumping should be continued until sufficient time has elapsed to clean the line before sample is taken. The drip valve should be so regulated that the collecting of the material continues through the entire time of pumping.

When impracticable to follow the above method it is recommended that samples be taken from the storage tank at three different levels.

Material in barrels or drums at a plant should be sampled by taking samples from not less than 3 per cent of the containers.

Whenever possible, the portion of the sample from each drum or barrel should be taken from near the heart of the barrel after it has been split open. Where samples must be taken from the top of the barrel, the material lying within 3 inches of the surface should not be included. A hatchet or any sharp-pointed tool is suitable for the purpose of digging into the barrel. (IMPORTANT.—Do not use kerosene on the blade.) The several portions are then to be pressed in a can of not less than 1 quart capacity, using a quantity of material which will nearly fill the can, which is then to be tightly covered. If cans are not available and some other type of container is used, it must be entirely free from paper or any other substance to which the bituminous material adheres readily.

Check field samples are recommended on plant-inspected material.

Field sampling.—For barrel shipments, see plant barrel sampling.

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[14] Intervals of 500 feet are suggested.

Sampling fluid products.—When a fluid material is shipped in tank cars, and the sample is to be taken directly from the tank car to represent an average of the entire tank-car contents, the following method is suggested:

A tin can, with a tight-fitting removable cover and wire handle, is secured, and a number of holes one-eighth of an inch in diameter are punched in the cover. This bucket is then weighted in any convenient way and lowered slowly by means of a cord attached to the handle through the entire depth of the tank car, so that the can will be filled with material from all depths of the car. This can is then emptied into another can of at least 1 quart capacity having a screw top or other equally tight cap or cover. A sample is more representative when the tank car has been agitated before the sample is taken.

Where individual samples are desired to check the uniformity of material throughout a tank car, it is suggested that thief samples be taken from top and middle and a third sample be taken from the outlet valve through which a sufficient amount of bituminous material has been allowed to flow in order to clean the valve properly.

Semisolid products.—Barrel shipments are to be sampled as in plant sampling.

Tank-car shipments are to be sampled through the dome by the use of a clean hot shovel.

Bituminous aggregates.[15]—It is suggested that a 5-pound sample be submitted when the material is sampled before being placed in the pavement.

Samples of pavements should be at least 1 square foot in area.

The material should be carefully boxed in order that it may remain intact during transit.

59. SAMPLING PORTLAND CEMENT.

See test No. 17.

60. SAMPLING PAVING BRICK.

See test No. 18.

61. SAMPLING METAL CULVERTS.

Owing to lack of uniformity of spelter coating on culvert sheets, it is recommended that as many samples as possible be taken from different culverts, each sample to be about 3 inches square.

The samples should be straightened preferably in a press or vise—*under no circumstances should they be hammered.*

62. SAMPLING OF PAINT AND PAINT MATERIALS.

Where a shipment of such material consists of a number of separate packages a sample should be taken from a sufficient number of such packages to give a representative composite sample. The contents of the containers should be stirred to homogeneous consistency before sampling.

In case of mixed paints, oils, and thinners the sample should be at least a pint. Preferably the sample should be placed in an air-tight friction top can. In the case of pastes and dried pigments the sample should be approximately 1 pound.

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[15] The term "bituminous aggregate" is defined as follows: The mineral or other aggregate, together with the bitumen which is used as the cementing medium.

MISCELLANEOUS MATTER.

63. LIST OF APPARATUS FOR CONDUCTING TESTS ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION.[16]

Analytical balance with necessary weights.
Rough balance.
Pycnometer—Hubbard-Carmick type.
Hydrometers and jar.
Penetrometer.
Constant temperature oven.
Open cup flash tester.
Ring and ball apparatus.
Ductility machine.
Erlenmeyer flasks.
Porcelain gooch crucibles and asbestos.
Aluminum float with three brass collars.
Engler flasks (250 c. c. distillation flasks of special dimension).
Condenser tubes.
25 c. c. graduates.
Sprengel tubes.
Copper still, with steel clamps, inside dimensions 6 by $3\frac{1}{2}$ inches.
Ring burner to fit copper still.
Engler viscosimeter with standard thermometer.
Extractor for bituminous mixes.
Platinum crucible, cover and triangle.
Vacuum pump.
Spatula knives.
Stop watch.
Burners, Meker and Tirrill.
Rubber tubing.
Stirring rods.
Tripods.
Thermometers.
Triangles.
Wire gauze.
Hot plate.
Water still.
Desiccator.
3-ounce tin cans, deep pattern, Gill type, American Can Co.
2-ounce tin cans.

64. LIST OF APPARATUS FOR PHYSICAL TESTING OF NONBITUMINOUS ROAD MATERIALS.[17]

1 Deval abrasion machine with four cylinders.
1 impact machine for toughness test (optional).
1 diamond-core drill, with suitable drill press (optional).
1 diamond saw (optional).
1 grinding lap (optional).
5 pounds No. 120 carborundum.
1 forcing press for breaking samples for Deval test (optional).
1 scale, capacity 5 kilograms and sensitive to 0.5 gram.
1 scale, capacity 1,000 grams and sensitive to 0.1 gram.
1 large drying oven.
1 10-inch desiccator, with calcium chloride.
1 millimeter scale.
1 100 c. c. graduate.
1 100 c. c. beaker.
1 16-inch sieve, reinforced, with square openings $\frac{1}{16}$ inch in size.
1 50-pound anvil.
1 10-pound sledge.
1 3-pound double-face stone hammer.
1 $1\frac{1}{2}$-pound single-face stone hammer.
1 6-inch scoop.
1 cement-testing machine.
1 200,000-pound testing machine, Universal type (optional).
6 3-gang cement molds.
1 set of Gilmore needles } one optional.
1 Vicat needle }
1 complete set of standard screens and sieves.
1 platform scale.
1 mixing pan for concrete, 3 by 4 feet.
1 large trowel.
1 small trowel.
1 sieve agitator.
1 cement-mixing table with nonabsorbent top.
1 nonabsorbent closet for storage of briquettes.
1 apparatus for accelerated soundness test.
6 pieces plate glass, 4 by 12 inches.
6 pieces plate glass, 4 by 4 inches.
1 immersion tank for storage of briquettes.
1 pair seamless rubber gloves.
12 6 by 12 inch cylindrical molds with metal base plates.
1 truncated cone for slump test, 4 by 12 by 8 inches.
1 specific gravity vessel (Bull. 555, U. S. Dept. of Agric., fig. 1).
1 Le Chatelier specific gravity flask.
100-pound bag standard Ottawa sand.
1 $\frac{1}{4}$-cubic foot cylindrical measure.
1 cubic foot measure.
1 tempering tank for mixing water.
1 puddling bar $\frac{5}{8}$ by 21 inches.

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[16] This list includes those items of equipment that would be used ordinarily. A number of additional pieces of apparatus might be required for occasional tests.

[17] This list includes items of equipment that will be used continuously and also certain items of equipment which will be used only occasionally, and these latter are indicated as "optional."

65. THE MANUFACTURE AND USE OF LABORATORY DIAMOND CORE DRILLS.

Black carbons or diamonds used for laboratory drills should range from $\frac{1}{16}$ to $\frac{3}{32}$ inch in size, and should be dense and regular in shape. Diamonds suitable for the work will weigh in the neighborhood of 0.1 carat each and from six to eight diamonds are required for a 1-inch drill. They may be obtained from any of the diamond importers.

The diamond drill consists of a bronze crown soldered to the end of a seamless steel tube about $4\frac{1}{2}$ inches long and $1\frac{1}{8}$ inches outside diameter and carrying six diamonds, each about $\frac{3}{32}$ inch in diameter. The other end of the steel tube carries a No. 2 Morse taper hollow drill shank through which water is admitted to the inside of the drill. The drill crown proper is made of Tobin bronze, 1-inch internal diameter, $1\frac{7}{32}$-inch external diameter, $\frac{1}{4}$ inch high, with a recess $\frac{3}{32}$ inch in depth by $1\frac{1}{8}$ inches in diameter in which the steel tube is soldered. Figure 3 gives a detailed view of the drill crown showing the various dimensions. In figure 36 are shown the various pieces of apparatus used in the operation of setting the diamonds in the drill crown. *A* is a piece of cold-drawn steel $1\frac{1}{4}$ by $\frac{1}{2}$ by 6 inches with a yoke *C* and thumbscrew and is used to

FIG. 36.—Apparatus used in manufacture of diamond drill.

hold the drill crowns. After mounting a crown in the clamp as shown, six holes are drilled in the face of the crown at equal distances apart, three of the holes almost breaking through the outside of the face of the ring and three almost breaking through the inside of the face. The holes should be slightly smaller than the diamonds which are to be used, and each should be slightly nicked on the thin edge with a fine file. A diamond is now placed in one of the holes, gently tapped with a piece of brass so as to hold it in place, after which the crown is placed in a small jeweler's vice "*D*" having jaws of soft steel or brass and with which the diamond is forced into the hole. Should the diamond not stand the pressure and crumble, it is not fit for drilling and should be used for other purposes. It should be possible to force any diamond good enough for drilling purposes into a hole in the above manner. Flat drills *B*, made of $\frac{1}{8}$-inch drill rod, turned to about $\frac{1}{2}$ inch long and of a size slightly smaller than the diamonds, are used for drilling the holes. It has been found that the flat drills are better than twist drills for they are stiffer and do away with a center punch. After the diamonds are all set, the drill is soft soldered to the end of the steel tube and is then ready for use.

Any drill press equipped with a hollow spindle and with the table so arranged that the water carrying the rock cuttings may be properly collected and carried away is satisfactory for use in rock drilling. A drill press carrying a No. 2 Morse taper is large enough. The speed of the drill should be in the neighborhood of 300 revolutions per minute.

Great care should be exercised when first using a diamond drill. A block of very soft limestone or sandstone should be selected and a number of cores cut from this stone until it is found that the drill is working properly, after which it may be used

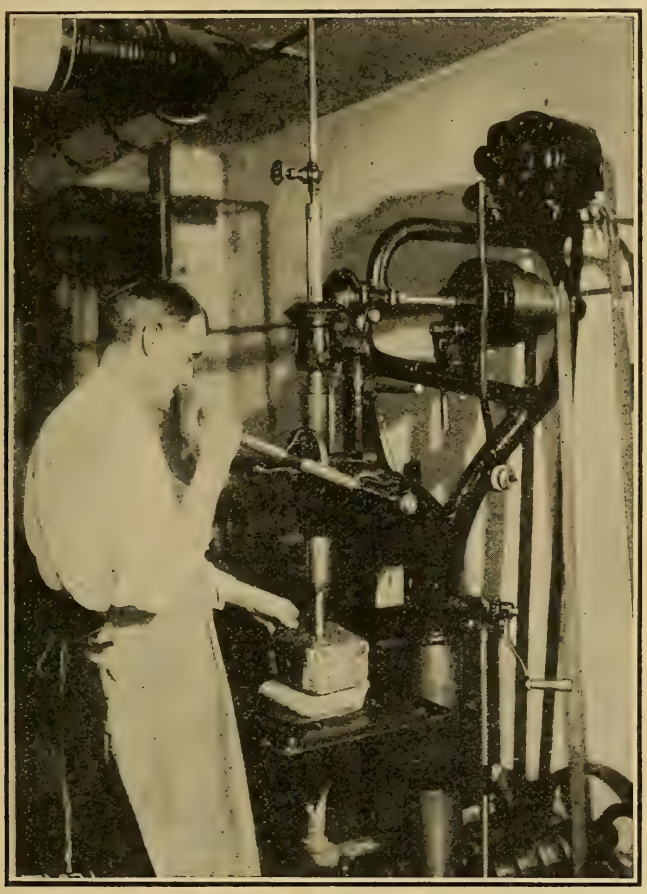

FIG. 37.—Diamond drill in use.

on harder rock. The sample should be bedded on a bag filled with sand as shown in figure 37, or in the case of very small pieces, it may be necessary to mount the samples in plaster of Paris before drilling. Plenty of water should be used on the inside of the drill so as to keep the space under the crown entirely free from rock cuttings, which, especially in the case of soft rock, have a tendency to "gum up" the drill. After one or two cores have been drilled, their diameter should be measured, and if it is found that the drill is cutting cores more than 25 mm. or less than 24 mm. in diameter, one or two of the diamonds must be reset. If the drill crown is turned to the dimen-

sions shown, however, and the diamonds set as indicated, the cores should come out very close to 25 mm. in diameter. The pressure should be applied always by hand and never automatically on account of the tendency of carbons to shatter if subjected to any appreciable impact. When drilling stone by hand, the pressure on the drill may be regulated in accordance with the character of the material being drilled. This is, of course, not the case if an automatic feed is used. A much greater pressure may be used when drilling fine-grained, homogeneous materials, such as trap, even if the rock is very hard, than in the case of coarse-grained, non-homogeneous materials or stone in which minerals of greater hardness than the mass of the rock are embedded. With a properly constructed drill, it should be possible to cut a core 4 inches in length from rock of medium hardness in about 10 minutes. Properly constructed drills will cut from 20 to 50 feet of rock, depending, of course, on the average hardness of the stone being used.

66. FORMS FOR RECORDING AND REPORTING RESULTS.

(Name of laboratory.)

ROCK TESTS.

Serial No...... *From*..... (County.) (State.) *Name*.....

SPECIFIC GRAVITY—ABSORPTION.

	(1)	(2)
Wt. in air		
Wt. in water		
Loss in wt.		
Wt. 96 hrs.		
Gain 96 hrs.		
Sp. gr.		
Absorption		

Sp. gr.....; Wt. cu. ft.....

Abs. lbs. cu. ft.....

Tested by....., Compt....., Chk.....

CEMENTING VALUE.

1..... 2..... 3..... 4..... 5.....

Avg. No. blows.....

Tested by....., Compt....., Chk.....

ABRASION.

No. pieces.....

Initial wt.....

Final wt.....

Under $\frac{1}{16}$ in.....

Per cent wear....., Fr. coef.....

Tested by....., Compt....., Chk...

COMPRESSION.

	(1)	(2)
Diam. cyl.		
Sec. area		
Total load		
Unit load		

Cr. str. lbs. per sq. in.....

Tested by....., Compt....., Chk...

HARDNESS.

	(1)	(2)
Initial wt.		
Final wt.		
Loss 1,000 rev.		
Loss.....rev.		

Hard. coef.....

Avg. hard. coef.....

Tested by....., Compt....., Chk.....

TOUGHNESS.

	(1)	(2)
Ht. blow cms.		

Av. toughness.....

Tested by....., Compt....., Chk.....

Remarks:..... *Reported*.....

(Name of laboratory.)

SAND AND GRAVEL TESTS.

Serial No. ..... *From* ..... (Town) ..... (County) ..... (State) *Name* .....

MECHANICAL ANALYSIS.

Pass.—Ret.	Wt.	%	Pass.—Ret.	Wt.	%
Over 3 in.			¼ in.—No. 10		
3 in.—2½ in.			No. 10—No. 20		
2½ in.—2 in.			No. 20—No. 30		
2 in.—1½ in.			No. 30—No. 40		
1½ in.—1 in.			No. 40—No. 50		
1 in.—¾ in.			No. 50—No. 80		
¾ in.—½ in.			No. 80—No. 100		
½ in.—¼ in.			No. 100—No. 200		
Over ¼ in.			Under No. 200		
Original wt.					

Tested by ..... Compt ..... Chk .....

UNDER NO. 200 MESH BY WASHING.

Orig. wt ..... ; final wt ..... ; loss .....

Per cent loss .....

Tested by ..... Compt ..... Chk .....

TENSION TESTS.

Sample Sand.		Ottawa Sand.	
7-day.	28-day.	7-day.	28-day.
Ave.			

Strength ratio, 7 days ..... %; 28 days ..... %

Water used, sample ..... Ottawa .....

Made by ..... Date .....

Tested by ..... at 7 days; by ..... at 28 days.

CEMENTING VALUE.

1 ....., 2 ....., 3 ....., 4 ....., 5 ..... Ave. .....

Tested by ..... Compt ..... Chk .....

Remarks: .....

Received .....

Reported, 7-day ..... ; 28-day .....

(Name of laboratory.)

CEMENT TESTS

Serial No. ..... *Marked* ..... *Received* ..... *Name* .....

Sent by ..... *From* .....

(County.) (State.)

At request of ..... *Condition* ..... *Weight* .....

SPECIFIC GRAVITY (Le Chatelier):

1. ..... Made by ..... Date .....

2. .....(Ignited.) Made by ..... Date .....

FINENESS: Made by ..... Date .....

Passing No. 100 sieve ..... %

Passing No. 200 sieve ..... %

TIME OF SETTING: Made by ..... Date .....

Initial ..... hr. ..... min.

Final ..... hr. ..... min.

SOUNDNESS:

Pat steamed 5 hrs. .....

.....

Pat in air 28 days .....

.....

Pat in water 28 days .....

.....

NORMAL CONSISTENCY:

.....

TENSILE STRENGTH:

Neat Made by ..... Date .....

24 hour.	7 day.	28 day.		
Ave.				

1 : 3 Made by ..... Date .....

Ave.				

..... SO_3 ..... MgO .....

REMARKS: .....

(Name of laboratory.)

BRICK TESTS

Serial No..... *Used*..... *Brand*.....
(Town.) (County.) (State.)

DIMENSIONS

Length, ins.	Breadth, ins.	Depth, ins.

Tested by..... Ck.....

ABSORPTION.

RATTLER TEST

CHARGE

	No.	Wt. Lbs.	
Large spheres.....	.....	.....	.....
Small spheres.....	.....	.....	.....
Total charge.....	.....	.....	.....

RUNNING DATA

Initial wt.....	.....lbs.	Revolutions	Time
Final wt.....	.....lbs.	Begin.....	.....
Loss.....	.....lbs.	End.....	.....

Per cent Loss.....

Tested by....., Compt....., Ck.....

No. of Tests since last inspection.....

Remarks.....

.....

Received..... *Reported*.....

(Name and location of laboratory.)

REPORT ON SAMPLE OF ROCK OR SLAG.

Laboratory No. .....

.....,192....
(Date reported.)

Name.....

Identification marks.....

Submitted by..... Title..... Address.....

Sampled....., 192... Received....., 192..

Sampled from.....

Quantity represented.....

Source of material.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

Specific gravity.....

Weight per cubic foot, in pounds.....

Water absorbed per cubic foot, ...pounds .....per cent

Per cent of wear..... .....

French coefficient of wear..... .....

Hardness..... .....

Toughness..... .....

Remarks:

Respectfully submitted.

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF GRAVEL OR SAND.

Laboratory No. .....

....., 192...
(Date reported.)

Name.....

Identification marks.....

Submitted by..... Title..... Address.....

Sampled....., 192... Received....., 192...

Sampled from.....

Quantity represented.....

Source of material.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

SAND. Mechanical analysis.		GRAVEL. Mechanical analysis.	
Fraction.	Per cent.	Fraction.	Per cent.
Retained ¼-inch screen		Retained 3-inch screen	
Passing ¼-inch retained 10 mesh		Passing 3-inch retained 2½ inch	
Passing 10 mesh retained 20 mesh		Passing 2½-inch retained 2 inch	
Passing 20 mesh retained 30 mesh		Passing 2-inch retained 1½ inch	
Passing 30 mesh retained 40 mesh		Passing 1½-inch retained 1 inch	
Passing 40 mesh retained 50 mesh		Passing 1-inch retained ¾ inch	
Passing 50 mesh retained 60 mesh		Passing ¾-inch retained ½ inch	
Passing 60 mesh retained 80 mesh		Passing ½-inch retained ¼ inch	
Passing 80 mesh retained 100 mesh		Passing ¼-inch screen	
Passing 100 mesh retained 200 mesh			
Passing 200 mesh			
Total		Total	
Silt in sand		Per cent of wear	

Tensile strength (cement-sand briquettes, 1:3).	Sample sand.			Standard Ottawa sand.		
	3-day.	7-day.	28-day.	3-day.	7-day.	28-day.
1						
2						
3						
4						
5						
Average						
Ratio						

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF SEMI-GRAVEL, TOP SOIL, OR SAND CLAY

Laboratory No. ...., 192..
(Date reported.)

Name.....

Identification marks .....

Submitted by..... Title..... Address.....

Sampled....., 192.. Received....., 192..

Sampled from .....

Quantity represented .....

Source of material.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

Analysis of material passing 10-mesh sieve.

	Per cent.	Per cent.	Per cent.	Character.
Sand retained, 20 mesh				
Passing 20, retained 60 mesh				
Passing 60, retained 100 mesh				
Passing 100, retained 200 mesh				
Total sand				
Silt				
Clay				
Total				
Total sand retained on 60 mesh				

Coarse material, ... per cent. Quality, ...

Mica, ...

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF PORTLAND CEMENT.

Laboratory No..... .....(Date reported.), 192...

Brand.....

Identification marks.....

Submitted by..... Title..... Address.....

Sampled....., 192... Received....., 192...

Sampled from.....

Quantity represented.....

Manufactured by.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

Chemical tests:

Loss on ignition, per cent.....

Insoluble residue, per cent.....

Sulphuric anhydride (SO_3), per cent.....

Magnesia (MgO), per cent.....

Physical tests:

Specific gravity.....

Per cent retained on 200-mesh sieve.....

Steam test.....

	Gillmore needle.		Vicat needle.
Initial set.....	.....	or	.....
Final set.....	.....	or	.....

Tensile strength (1 : 3 Ottawa sand):

7 days.	28 days.
.....	.....
.....	.....
.....	.....
Average:	Average: .....

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF VITRIFIED PAVING BRICK.

(Date reported.)

Laboratory No..... ....., 192..

Trade name.....

Identification marks.....

Submitted by..... Title..... Address.....

Sampled....., 192.. Received....., 192..

Sampled from.....

Quantity represented.....

Manufactured by.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

General data.

Average dimensions, length..... Width..... Depth.....

Drying treatment.....

Standardization data.

	Weight of charge (after standardization).	Number of fresh stave liners.	Repairs affecting barrel.
10 large spheres.....	.....	.....	.....
small spheres.....	.....	.....	.....
Total.....	.....	.....	.....

Number of charges tested since last inspection, ...

Running data.

	Time readings.			Revolution counter readings.	Running notes, stops, etc.
	Hours.	*Minutes.*	*Seconds.*		
Beginning of test.....	.....	.....	.....	.....	.....
Final reading.....	.....	.....	.....	.....	.....

Initial weight of 10 bricks..... .... Maximum variation in per cent loss.

Final weight of 10 bricks..... ....

Loss of weight..... ....

Loss of weight, per cent..... ....

Number of bricks broken in test. . ...

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF (TARS OR TAR PRODUCTS).

Laboratory No. ...., 192...
Identification marks: .....
Submitted by .....
Sampled ....., 192... Received ....., 192..
Sampled from .....
Quantity represented: .....
Trade name: .....
Manufactured by ..... at .....
Location used or to be used: .....
Examined for .....

TEST RESULTS.

GENERAL CHARACTERISTICS:
Water.....
Specific gravity, 25° C./25° C. .....
Specific viscosity, Engler, ... °C. .....
Float test, ... °C. [seconds] .....; ..... °C. [seconds] .....
Melting point .... [°C.] .....
Total bitumen (soluble in carbon disulphide) [per cent].....
Free carbon (organic matter insoluble) [per cent].....
Inorganic matter insoluble [per cent].....
Distillation

FRACTIONS.	CHARACTER.	% BY VOL.	% BY WT.
..... –170° C.	.....		
170° C.–235° C.	.....		
235° C.–270° C.	.....		
270° C.–300° C.	.....		
Residue	.....		

Specific gravity of distillate, 25° C./25° C. .....
Melting point of residue ..... [°C.] .....
Remarks:

Respectfully submitted,

.....
(Title.)

(Name and location of laboratory.)

REPORT ON SAMPLE OF (PETROLEUM OR ASPHALT PRODUCTS).

Laboratory No. ...., 192...
Identification marks: .....
Submitted by .....
Sampled ....., 192... Received ....., 192...
Sampled from .....
Quantity represented: .....
Trade name: .....
Manufactured by ..... at .....
Location used or to be used: .....
Examined for .....

TEST RESULTS.

GENERAL CHARACTERISTICS:
Specific gravity, 25° C./25° C. .....
Flash point .... [°C.] .....
Specific viscosity, Engler, ... °C. .....
Float test, ... °C. [seconds] .....; °C. [seconds] .....
Penetration, 0° C. 200 grams, 60 seconds .....
Penetration, 25° C. 100 grams, 5 seconds .....
Penetration, 46.1° C. 50 grams, 5 seconds .....
Melting point .... [°C.] .....
Ductility, ... °C. [cm.] .....; ..... °C. [cm.] .....
Loss, 163° C., 5 hours [per cent] .....
Characteristics of residue.
Consistency of residue { Penetration, 25° C. 100 grams, 5 seconds .....
Consistency of residue { Float test, ... °C. [seconds] .....; .... °C. [seconds] ...
Total bitumen (soluble in carbon disulphide) [per cent] .....
Organic matter insoluble [per cent] .....
Inorganic matter insoluble [per cent] .....
Per cent of total bitumen insoluble in 86° B. naphtha .....
Fixed carbon [per cent] .....
Remarks:

Respectfully submitted,

.....
(Title.)

(Name and location of laboratory.)

REPORT ON SAMPLE OF (MISCELLANEOUS MATERIALS).

Laboratory No. ...., 192...

Name .....

Identification marks .....

Submitted by .....

Sampled ....., 192... Received ....., 192...

Sampled from .....

Quantity represented .....

Source of material .....

Location used or to be used .....

Examined for .....

TEST RESULTS.

Respectfully submitted,

.....

(Title.)

(Name and location of laboratory.)

Laboratory No. .....

REPORT ON SAMPLE OF (MISCELLANEOUS MATERIALS).

Identification marks: .....

Submitted by .....

Sampled ....., 192 , from ..... Quantity represented: .....

Trade name: .....

Source of material: .....

Location used or to be used: .....

Examined for .....

General characteristics: .....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Received ....., 192 Acknowledged ....., 192 Examined ....., 192 Reported ....., 192 Analyst .....

(Name and location of laboratory.)

Laboratory No. .....

REPORT ON SAMPLE OF (TARS AND TAR PRODUCTS).

Identification marks: .....

Submitted by .....

Sampled ....., 192 , from ..... Quantity represented: .....

Trade name: .....

Manufactured by ..... at .....

Location used or to be used: .....

Examined for .....

General characteristics: .....

Specific gravity 25°/25° C. .....

Specific viscosity, Engler, ...° C. .....

Float Test, ...° C. (sec.) .....; .....° C. (sec.) .....

Melting point (° C.) .....

Total bitumen (soluble in CS_2) (per cent) .....

Free carbon (organic matter insoluble) (per cent) .....

Inorganic matter insoluble (per cent) .....

Water (per cent) .....

Distillation ..... Character	Per cent by vol.	Per cent by wt.
170° C.		
170°–235° C.		
235°–270° C.		
270°–300° C.		
Residue		
.....		

Specific gravity of distillate 25°/25° C. .....

Melting point of residue (°C.) .....

.....

.....

Received ....., 192 Acknowledged ....., 192 Examined ....., 192 Reported ....., 192 Analyst .....

(Name and location of laboratory.)

REPORT ON SAMPLE OF (PETROLEUM OR ASPHALT PRODUCTS).

Laboratory No. .....

Identification marks: .....

Submitted by .....

Sampled....., 192 , from ..... Quantity represented: .....

Trade name: .....

Manufactured by ..... at .....

Location used or to be used: .....

Examined for .....

General characteristics: ..... Ductility.....° C. (cm.) .....

Specific gravity 25°/25° C. ..... Loss, 163° C., 5 hours (per cent) .....

Flash point (° C.) ..... Characteristics of residue: .....

Burning point (° C.) ..... Penetration of residue 25° C., 100 grams, 5 seconds .....

Specific viscosity, Engler, ...° C. ..... Float test of residue.....° C. (sec.) .....; ° C. (sec.) .....

Float test, ...° C. (sec.) .....; .....° C. (sec.) ..... Total bitumen (soluble in CS_2) (per cent) .....

Penetration, 0° C., 200 grams, 60 seconds ..... Organic matter insoluble (per cent) .....

Penetration, 25° C., 100 grams, 5 seconds ..... Inorganic matter insoluble (per cent) .....

Penetration, 46.1° C., 50 grams. 5 seconds ..... Per cent of total bitumen insoluble in 86° B. naphtha .....

Melting point (° C.) ..... Fixed carbon (per cent) .....

.....

Received....., 192 Acknowledged..... 192 Examined..... 192 Reported..... ., 192 Analyst.....

67. COMPARISON OF DEGREES BAUMÉ AND SPECIFIC GRAVITY.

(Liquids lighter than water.)

$$(1)\ \text{Sp. gr.}=\frac{140}{130+°\text{B.}}\ \text{at } 15.5°\text{ C.} \quad (2)\ °\text{B.}=\frac{140}{\text{Sp. gr.}}-130 \text{ at } 15.5°\text{ C.}$$

°B.	Sp. gr.	°B.	Sp. gr.	°B.	Sp. gr.	°B.	Sp. gr.
10	1.0000	31	0.8695	52	0.7692	73	0.6896
11	.9929	32	.8641	53	.7650	74	.6863
12	.9859	33	.8588	54	.7609	75	.6829
13	.9790	34	.8536	55	.7567	76	.6796
14	.9722	35	.8484	56	.7526	77	.6763
15	.9655	36	.8433	57	.7486	78	.6731
16	.9589	37	.8383	58	.7446	79	.6698
17	.9523	38	.8333	59	.7407	80	.6666
18	.9459	39	.8284	60	.7368	81	.6635
19	.9395	40	.8235	61	.7330	82	.6604
20	.9333	41	.8187	62	.7292	83	.6573
21	.9271	42	.8139	63	.7254	84	.6542
22	.9210	43	.8092	64	.7216	85	.6511
23	.9150	44	.8045	65	.7179	86	.6482
24	.9090	45	.8000	66	.7143	87	.6452
25	.9032	46	.7954	67	.7167	88	.6422
26	.8974	47	.7909	68	.7071	89	.6393
27	.8917	48	.7865	69	.7035	90	.6363
28	.8860	49	.7821	70	.7000		
29	.8805	50	.7777	71	.6965		
30	.8750	51	.7734	72	.6931		

68. COMPARISON OF CENTIGRADE AND FAHRENHEIT DEGREES.

$$(1)\ °\text{F.}=\frac{9}{5}°\text{C.}+32. \quad (2)\ °\text{C.}=\frac{5(°\text{F.}-32)}{9}.$$

C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.
0	32.0	38	100.4	76	168.8	114	237.2	152	305.6	190	374.0
1	33.8	39	102 2	77	170.6	115	239.0	153	307.4	191	375.8
2	35.6	40	104.0	78	172.4	116	240.8	154	309.2	192	377.6
3	37.4	41	105.8	79	174.2	117	242.6	155	311.0	193	379.4
4	39.2	42	107.6	80	176.0	118	244.4	156	312.8	194	381.2
5	41.0	43	109.4	81	177.8	119	246.2	157	314.6	195	383.0
6	42.8	44	111.2	82	179.6	120	248.0	158	316.4	196	384.8
7	44.6	45	113.0	83	181.4	121	249.8	159	318.2	197	386.6
8	46.4	46	114.8	84	183.2	122	251.6	160	320.0	198	388.4
9	48.2	47	116.6	85	185.0	123	253.4	161	321.8	199	390.2
10	50.0	48	118.4	86	186.8	124	255.2	162	323.6	200	392.0
11	51.8	49	120.2	87	188.6	125	257.0	163	325.4	201	393.8
12	53.6	50	122.0	88	190.4	126	258.8	164	327.2	202	395.6
13	55.4	51	123.8	89	192.2	127	260.6	165	329.0	203	397.4
14	57.2	52	125.6	90	194.0	128	262.4	166	330.8	204	399.2
15	59.0	53	127.5	91	195.8	129	264.2	167	332.6	205	401.0
16	60.8	54	129.2	92	197.6	130	266.0	168	334.4	206	402.8
17	62.6	55	131.0	93	199.4	131	267.8	169	336.2	207	404.6
18	64.4	56	132.8	94	201.2	132	269.6	170	338.0	208	406.4
19	66.2	57	134.6	95	203.0	133	271.4	171	339.8	209	408.2
20	68.0	58	136.4	96	204.8	134	273.2	172	341.6	210	410.0
21	69.8	59	138.2	97	206.6	135	275.0	173	343.4	220	428.0
22	71.6	60	140.0	98	208.4	136	276.8	174	345.2	230	446.0
23	73.4	61	141.8	99	210.2	137	278.6	175	347.0	240	464.0
24	75.2	62	143.6	100	212.0	138	280.4	176	348.8	250	482.0
25	77.0	63	145.4	101	213.8	139	282.2	177	350.6	260	500.0
26	78.8	64	147.2	102	215.6	140	284.0	178	352.4	270	518.0
27	80.6	65	149.0	103	217.4	141	285.8	179	354.2	280	536.0
28	82.4	66	150.8	104	219.2	142	287.6	180	356.0	290	554.0
29	84.2	67	152.6	105	221.0	143	289.4	181	357.8	300	572.0
30	86.0	68	154.4	106	222.8	144	291.2	182	359.6	350	662.0
31	87.8	69	156.2	107	224.6	145	293.0	183	361.4	400	752.0
32	89.6	70	158.0	108	226.4	146	294.8	184	363.2	450	842.0
33	91.4	71	159.8	109	228.2	147	296.6	185	365.0	500	932.0
34	93.2	72	161.6	110	230.0	148	298.4	186	366.8	550	1,022.0
35	95.0	73	163.4	111	231.8	149	300.2	187	368.6	600	1,112.0
36	96.8	74	165.2	112	233.6	150	302.0	188	370.4	650	1,202.0
37	98.6	75	167.0	113	235.4	151	303.8	189	372.2	700	1,292.0

69. METRIC CONVERSION TABLES.

Length.		Capacity.		Mass.	
Inches.	Millimeters.	United States liquid ounces.	Cubic centimeters.	Avoirdupois ounces.	Grams.
$\frac{1}{32}$=0.0312	0.7938	1	29.574	1	28.3495
$\frac{1}{16}$= .0625	1.5875	2	59.147	2	56.6991
$\frac{1}{8}$= .1250	3.1750	3	88.721	3	85.0486
$\frac{1}{4}$= .2500	6.3500	4	118.295	4	113.3981
$\frac{1}{2}$= .5000	12.7000	5	147.869	5	141.7476
1	25.4001	6	177.442	6	170.0972
2	50.8001	7	207.016	7	198.4467
3	76.2002	8	236.590	8	226.7962
4	101.6002	9	266.163	9	255.1457
5	127.0003	16=1 pt	473.18	16=1 lb	453.59
6	152.4003	32=1 qt	946.36	0.3527	10
7	177.8004	128=1 gal.	3,785.43	.7055	20
8	203.2004	0.3381	10	1.0582	30
9	228.6005	.6763	20	1.4110	40
		1.0144	30	1.7637	50
		1.3526	40	2.1164	60
	Centimeters.	1.6907	50	2.4692	70
		2.0288	60	2.8219	80
		2.3670	70	3.1747	90
		2.7051	80	3.5270	100
0.3937	1=10 mm.	3.0432	90	35.27	1,000=1 kilogram.
.7874	2	3.3810	100		
1.1811	3	33.81	1,000=1 liter.		
1.5748	4				
1.9685	5				
2.3622	6				
2.7559	7				
3.1496	8				
3.5433	9				

70. REFERENCES TO TESTS FOR PAINT AND PAINT MATERIALS, SEWER PIPE, DRAIN TILE, AND METALS.

Determination of Per cent Pigment in Paints (See Page 68).

Standard Methods for Routine Analysis of White Pigments.
(Refer to A. S. T. M. Standard Method, Serial Designation: D34–17.)

Standard Methods for Routine Analysis of Dry Red Lead.
(Refer to A. S. T. M. Standard Method, Serial Designation: D49–18.)

Standard Methods for Routine Analysis of Yellow, Orange, Red, and Brown Pigments containing Iron and Manganese.
(Refer to Standard Method, Serial Designation: D50–18.)

Standard Specifications for Turpentine.
(Refer to A. S. T. M. Standard, Serial Designation: D13–15.)

Standard Tests for Paint Thinners other than Turpentine.
(Refer to A. S. T. M. Standard Method, Serial Designation D28–17.)

Standard Specifications for Purity of Boiled Linseed Oil from North American Seed.
(Refer to A. S. T. M. Standard, Serial Designation: D11–15.)

Standard Specifications for Purity of Raw Linseed Oil from North American Seed.
(Refer to A. S. T. M. Standard, Serial Designation: D1–15.)

Tentative Specifications for Cement Concrete Sewer Pipe.
(Refer to A. S. T. M. Tentative Standard, Serial Designation: C14–19T.)

Standard Specifications for Drain Tile.
(Refer to A. S. T. M. Standard, Serial Designation: C4–16.)

Tentative Specifications for Clay Sewer Pipe.
(Refer to A. S. T. M. Tentative Standard, Serial Designation: C13–18T.)

Tests for Spelter Coatings on Culvert Metals.
(See page 68.)

Standard Specifications for Structural Steel for Bridges.
(Refer to A. S. T. M. Standard Method, Serial Designation: A7–16.)

Standard Methods for Chemical Analysis of Plain Carbon Steel.
(Refer to A. S. T. M. Standard Method, Serial Designation: A33–14.)

Standard Specifications for Billet Steel Concrete Reinforcement Bars.
(Refer to A. S. T. M. Standard Method, Serial Designation: A15–14.)

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Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. June 15, 1921

REGIONAL DEVELOPMENT OF PULPWOOD RESOURCES OF THE TONGASS NATIONAL FOREST, ALASKA.

By CLINTON G. SMITH, *Forest Inspector.*

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OBJECTS OF THIS STATEMENT.

This statement has been prepared to aid those who wish information on the timber and other resources of the Tongass National Forest in Alaska, to indicate the capital and organization necessary for the development of Alaskan pulp and paper mills, to show what data on the timber resources of that region have been and are being collected by the Forest Service, and to outline the conditions of purchase of timber on the National Forests.[1]

[1] Acknowledgment is made to the Forest Products Laboratory for technical features; particularly to a report by H. E. Surface, entitled "Conditions Existing for the Manufacture of Pulp and Paper in Alaska," material from which has been freely used; and also to the district forester at Portland, Oreg., for valuable assistance.

DEMAND FOR PULP AND PAPER.

The time seems to be ripe for the extensive exploitation of Alaskan pulpwood. The successful operation of pulp and paper mills in near-by British Columbia, which has practically similar timber and power resources and comparable transportation facilities, removes the speculative element from the proposed development. The demand for paper has increased to such an extent that it has become possible for well-organized and adequately financed companies to operate pulp and paper mills on an extensive scale, particularly for making newsprint. Ten years ago the United States produced its entire supply of newsprint. In 1919 two-thirds of it was imported, mostly from Canada; and Canadian supplies are not without limit.[2] All indications point to a continuance of the demand at prices which should make possible profitable operations in Alaska.

New sources are imperatively required for the supply of raw pulpwood. This need has already brought mills to the Pacific coast. They were located, first in California, Washington, and Oregon, and then in British Columbia. The same transition has taken place in the lumber industry, and the production of lumber in the Pacific Northwest is increasing steadily. The movement in the pulp industry, however, is necessarily slower, because of the greater investment called for per unit and the very large requirement for power. Furthermore, the pulp industry demands an assured permanent supply of raw material and a proper allocation of water power under stable tenure, both of which requisites are found in the Tongass National Forest in southeastern Alaska. It is the policy of the Forest Service to sell pulpwood from the National Forests with such provisions for future supply as will assure the permanence of the industry.

ADVANTAGES OF REGIONAL DEVELOPMENT.

There is room for a number of mills on the Tongass Forest. When these are in operation, together with the established mills of British Columbia, which are reported[3] to represent an investment of $42,000,000, they will constitute a producing region whose products will have a recognized standing in the world's markets. The development of this region will facilitate the procurement of sales contracts and needed capital, make it possible to attract both skilled and unskilled labor, and, lastly, but by no means of least importance, enable the industry to secure favorable conditions and rates for the transportation of its products. These are prime factors in the success of an operation of any magnitude, and are recognized as such.

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[2] See "Some Startling Facts About Canada's Forests," by Frank D. Barnjum, in the Pulp and Paper Magazine of Canada, Jan. 1, 1920, reprints of which are available from the publishers.

[3] See consular letter of J. J. Johnson, Feb. 20, 1920.

Well-known examples of regional localization of industry are steel production at Pittsburgh and Gary, the making of automobiles at Detroit, textile and other manufacturing in New England, and so on. The possibilities of regional development can scarcely be overemphasized.

Pioneer conditions of the region have been met and overcome by the successful establishment of mills in near-by British Columbia. After much expenditure of time and money, and in spite of some reverses, a number of going concerns are manufacturing pulp and paper in British Columbia along the coast between Seattle and Prince Rupert.

Some of the earlier projects on the Pacific coast were started before the time was ripe for their success. The prices for products were too low to offset the costs involved in establishing a new industry far removed from consuming centers and with consequent high transportation charges. The paper shortage has radically changed the situation. Market requirements necessitate an expansion of the industry and seem to preclude a return to the old-time price levels.

IMPORTANCE OF ALASKA AS A SOURCE OF PAPER SUPPLY.

Secretary of Agriculture Meredith recently said:

> Alaska is destined to become a second Norway. With her enormous forests of rapidly growing species suitable for pulp, her water power, and her tidewater shipment of manufactured products, Alaska will undoubtedly become one of the principal paper sources of the United States. A substantial development of the paper industry in this wonderful region, combined with the intelligent reforestation of pulp lands in the older regions, should settle forever the question of a paper shortage in the United States.

Within the last 10 years, he points out, "the Forest Service has brought about the sale of 420,000,000 feet of saw timber in the National Forests of Alaska."

The Department of Agriculture believes that the development of the forest and water-power resources of Alaska is a practicable means of increasing the supplies of newsprint available for the United States, and therefore of eventually lessening the paper shortage now so acute. The National Forests of Alaska probably contain 100,000,000 cords of timber suitable for the manufacture of newsprint and other grades of paper. Under careful management these Forests can produce 2,000,000 cords of pulpwood annually for all time, or enough to manufacture one-third of the pulp products now consumed in the United States.

The Alaskan forests also contain the second chief essential of the paper-manufacturing industry—water power. While no accurate survey of water power has been made, known projects have a pos-

sible development of over 100,000 horsepower; and the Forest Service estimates that a complete exploration of the National Forests in southern Alaska will disclose their potential horsepower to be not less than a quarter of a million.

Scarcely any other part of the country offers a field for the upbuilding of a permanent pulp and paper industry equal to that afforded by Alaska. It is a virgin field because, in spite of its natural advantages and vast supplies of raw material, economic conditions had not, prior to 1919, become sufficiently favorable to attract capital. For years the Forest Service tried in vain to interest capital in the development of enterprises for paper production in Alaska. Had it succeeded these enterprises would now be in a very advantageous position.

It may be said in passing that the purpose of the Forest Service looks beyond merely finding a market for Government timber in order that the timber may be cut and a new growth started in its place. The Forests are administered as public properties created to serve public needs. Alaska's first need is capital. It has not yet reached a point at which the upbuilding of the Territory can be effected merely by an influx of pioneers of the type that conquered the wilderness in our Western States. While development must be a gradual process governed by economic facts, large-scale operations are essential. To the extent that conditions can be made favorable for such operations development will be hastened.

Public ownership of the National Forests and their administration in accordance with the general policy pursued by the Forest Service affords capital certain important advantages. The amount of the investment necessary is greatly reduced by the fact that the Service is in position to guarantee permanent supplies, on reasonable terms as to price, and made available as needed. In other words, the operator does not need to invest heavily in raw material or assume the speculative risks involved when timber must be carried for a number of years with accumulating charges before manufacture. Again, prospective operators do not have to negotiate with a number of different owners or spend time and money in building up an operating unit. It is the desire of the Government to facilitate the establishment of mills, and the Forest Service is therefore glad to make available all the information that it can secure and to offer terms and conditions of sale that will interpose no unnecessary or unreasonable obstacles to development.

The value to Alaska of a pulp and paper industry on the National Forests can scarcely be overstated. By creating a demand for labor it will build up the population; by creating a market for farmers' crops it will stimulate agricultural development; and it will improve transportation facilities and benefit all kinds of business. The Ter-

ritory has been losing population and retrograding commercially and industrially in the last few years, primarily because after the first cream of her mineral wealth had been skimmed general economic conditions were not favorable to immediate further progress. An alteration in these conditions now opens an opportunity to start the tide running the other way.

Obviously, the building up of Alaska generally will work to the advantage of any business enterprise located there, since it will make for better living conditions, greater contentment and stability of labor, and superior facilities of many kinds. At the same time that the interests of Alaska will be advanced by establishment of a local paper and pulp industry, such an industry will itself participate in the benefits of local development.

LOCATION OF THE REGION.

The timber described in this report is situated along the coast and on the large islands of southeastern Alaska, on the Tongass National Forest. The region is about as far west as it is north of Seattle and takes the one hundred and fiftieth meridian time, which is one hour slower than Pacific coast time. The largest towns in southern Alaska are Juneau and Ketchikan. Ketchikan, which lies at the extreme southern end, is only 670 miles from Seattle and approximately only one-third of the distance from Seattle to the well-known town of Dawson on the Yukon River, in the Klondike region. Ketchikan is only 60 hours by steamer from Seattle and is only 93 miles from Prince Rupert, British Columbia, the terminus of the Grand Trunk Pacific, a transcontinental railroad. The scheduled time for passenger trains from eastern points is seven days. It is possible to ship freight by car ferry from Ketchikan to Prince Rupert, and thence by rail eastward to its destination.

COMMUNICATION AND ACCESSIBILITY.

Southeastern Alaska is favored with numerous deep-water harbors open the year round, and there is comparatively smooth water in the straits and passages. This region is advantageously located, with reference to shipments by rail and water, to the United States and water shipments to the Orient, South America, and Australasia.

The distances by water and rail to important markets are:

From—	To—	Distance.
		Statute miles.
Prince Rupert	Chicago	2,658
	New York	3,566
	Seattle	932
Sitka	Chicago	3,113
	New York	4,021
	Boston	4,134

From—	To—	Distance.
		Nautical miles.[1]
Sitka	San Francisco	1,302
	New York	6,564
	Honolulu	2,386
	Sidney	6,806
	Wellington	6,499
San Francisco	New York (via Panama)	5,262
	New York (via Magellan Strait)	13,135
	Yokohama	4,536
	Shanghai	5,387
	Manila	6,221
	Honolulu	2,091
	Panama	3,245
	Valparaiso	5,135

[1] A nautical mile equals 1.15 statute miles.

Regular mail service by boat to and from Alaska is maintained throughout the year. The region is served by a military cable to Seattle, available to the public. Wireless stations, both Government and private, are well distributed along the coast.

During the last two weeks in April, 1920, the West Coast Lumberman reported that about 100 cargoes for Alaska were loaded at Portland. Most of these cargoes were destined for the canneries. Several steamship lines ply regularly from Alaska to the "outside." The Pacific Coast Steamship Co. operates four steamships. The Alaska Steamship Co. operates five passenger steamships and nine freight steamers. The Grand Trunk Pacific operates in the Alaskan service two steamers and the Canadian Pacific one.[4] The Union Steamship Co. operates 10 steamers to Alaskan ports. There are a number of other boats operating to Alaska, and at Ketchikan the number of clearances of vessels per year is in the neighborhood of 2,000.

From the regular ports of call reached by coastwise steamers, fishing boats, and mail boats, the outlying regions are reached only by special trips with gasoline boats. The type of boat used most successfully by the Forest Service is 45 feet long, and should have a crew of two men; but the Service does not have the facilities to take interested parties on investigating trips for timber and power-site locations. There are, however, a limited number of boats for hire at all the principal ports at rates depending on the demand for the service and the character of the trip.

TOPOGRAPHIC AND OTHER SURFACE FEATURES.

Burchard (U. S. Geological Survey Bulletin 592, 1914, p. 97), describes the general topographic and surface features as follows:

The mainland and islands of southeastern Alaska are generally mountainous, and there is little level land either as upland area or along the shores. Along

[4] The Merchant Marine Act of June 15, 1920, makes certain restrictions upon the transportation of merchandise, and any one interested in Alaska would do well to familiarize himself with the provisions of this act.

much of the coast line the hills and mountains rise abruptly[5] and the dense forest growth, extending down to the level of high tide, overhangs the steep banks. The islands are separated by an intricate system of waterways and fiords, known locally as straits, canals, channels, passages, sounds, narrows, inlets, bays, coves, and arms, some of which reach far inland. Many of these waterways are very deep and can be safely navigated by the largest ocean steamers, but some are so shallow as to be navigable only at high tide by boats of moderate draft. The coast and entrances to harbors are rocky and in places the greatest care is necessary in order to avoid rocks that are barely submerged. The topography is so rough that only in favored localities or at great expense can wagon or tram roads be constructed. The waterways are, therefore, of great value in affording routes of communication between different portions of the region and between this region and the Pacific coast ports of the United States. Indeed, were it not for water transportation the mining and quarrying industries in southeastern Alaska could scarcely have been developed.

The rock surface is in general thickly overgrown with small to medium-sized timber and dense underbrush and has a soil cover of decayed wood, moss, and mold, from a few inches to 3 or 4 feet thick as a rule, but thicker in hollows and crevices in the rock.

CLIMATE OF THE REGION.

Accurate climatic data for the region, based on observations taken at all the larger towns, are available from the records of the Weather Bureau. It must be remembered that these data were taken near tidewater, and that the annual precipitation of a given catchment basin which includes country in the higher altitudes can not be assumed to be the same as at sea level. In this respect the data will be found lacking.

The dense forests bordering the shore line of southeastern Alaska are the result of the moist, humid climate. The records show that the annual rainfall ranges between 80 and 130 inches. Three-quarters of the precipitation occurs from March to November. In the high altitudes the winter precipitation is largely in the form of snow, and in consequence the winter run-off is much less than that of the rainy season.

There is a difference of only 2° in mean annual temperature between Puget Sound and Sitka. The mean temperature for January is 33° and for August 56°, an annual range of only 23° at Sitka. At Juneau, on the mainland, there is less oceanic influence, and the mean annual temperature is lower, the difference being more marked in winter than in summer. The harbors of southeastern Alaska are ice-free the year round, and the water is warm enough to favor the marine teredo, which is very active in salt water in southeastern Alaska, so much so that piles designed to be permanent must be coated with protective covering of cement or otherwise protected.

[5] Reaching a maximum elevation varying from 4,000 feet in the southern part to 7,000 feet in the northern.

Altitude has a profound effect on climate, and this is shown in tree growth. The limit of merchantable timber is found at about 2,500 feet above sea level.

Work in the open is possible at all times of the year, but logging operations are not profitable in the short days of winter. It is likely that a mill would rely on stored pulpwood for a three or four months' run. In Ketchikan it is said to be necessary to use artificial lights after 3 o'clock in the afternoon in December. It is stated that the low summer temperature would be of advantage in sulphite-mill practice.

TIMBER AND STAND.

The most widely distributed commercial tree on the Tongass Forest is western hemlock (*Tsuga heterophylla*). It is a rapidly growing tree, and is suitable for either mechanical or chemical pulp, either alone or in mixture with other species. It is conservatively estimated that it forms 60 per cent of the merchantable stand. It is being extensively used for pulp at a number of plants in British Columbia.

Sitka spruce (*Picea sitchensis*) forms about 20 per cent of the stand. It varies greatly in percentage of mixture, from pure stands of 10 acres or less to stands in which it is found only here and there. Spruce and hemlock form increasingly larger percentages of the stand of timber toward the north.

Other species forming approximately 20 per cent of the stand are western red cedar (*Thuja plicata*) and yellow cypress (*Chamæcyparis nootkatensis*) with a little cottonwood, birch, lodgepole pine, and white fir.

The stand of timber on the Tongass Forest is roughly estimated at 9,000 feet, board measure, per acre, and the timber forms a belt back from the coast that averages approximately 1 mile in width and varies from a minimum width of one-fourth mile or less to a maximum of 5 miles. An average stand of 20,000 feet per acre of merchantable timber was found in a cruise of the Behm Canal Unit, and individual stands of 100,000 feet per acre have been found over small areas. The Behm Canal Unit, as shown on the map, has a stand of approximately 1,000,000,000 feet, board measure, of which 88 per cent is spruce and hemlock. Spruce is used locally for lumber, box shooks, and piling; cedar for lumber and shingles; and hemlock for lumber and piling.

Practically all of the timber in southeastern Alaska is under the control of the Government and is within the boundaries of the National Forest, the exceptions being reservations and town sites. The area of land in private ownership is small.

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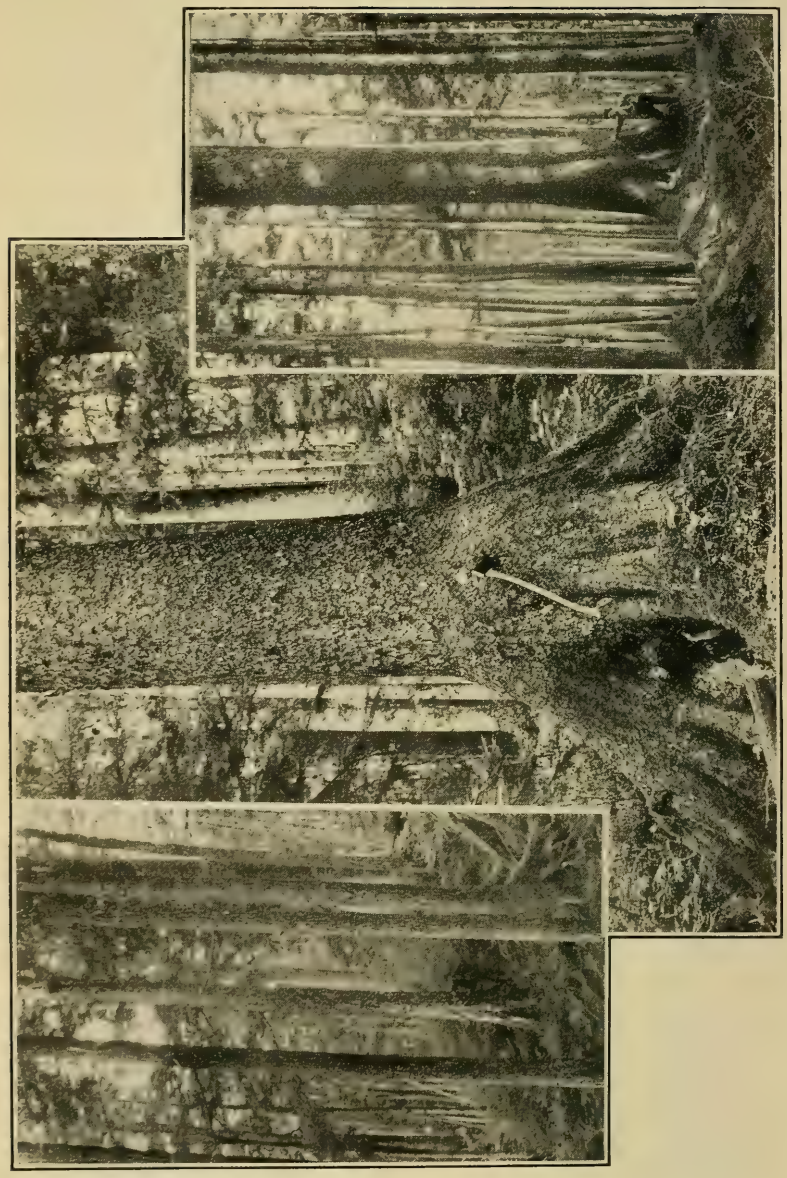
STAND OF HEMLOCK AND SPRUCE ON REVILLAGIGEDO ISLAND, TONGASS NATIONAL FOREST, ALASKA.

Western hemlock constitutes about 60 per cent and Sitka spruce about 20 per cent of the merchantable timber in southeastern Alaska.



STANDS OF SITKA SPRUCE AND WESTERN HEMLOCK, WITH "CLOSE-UP" SPRUCE IN CENTER, ON ALASKA NATIONAL FORESTS.

QUALITY OF TIMBER.

The spruce in the commercial sizes is generally sound and of good quality. The hemlock, however, is apt to be defective, the damage consisting of partial decay at the butt, "black knots," or fluted trunks. The latter defect is pronounced only in the butt logs of the smaller trees, the bark in the very worst cases being recessed almost to the center in three or four places around the circumference. The smaller and inferior trees of both species are apt to have numerous limbs extending near the ground. In general, hemlock is not the equal of the spruce for pulp making and for lumber, as well as for many other purposes, and its present stumpage price is therefore commonly about half that of spruce.

All estimates in this report are based on stands from which wood "merchantable for pulp" may be taken. For either hemlock or spruce, decay in butt logs of "merchantable pulpwood" seldom exceeds 15 to 20 per cent, and the decayed portion may be eliminated when the wood is prepared for pulp making; that is, when it is being split or "broken up" with saws. Even when timber is badly affected with "black knots," the knots may be completely removed at an additional cost for "preparing," over the ordinary cost, of about $1 per thousand for handwork; that is, chopping with an ax, as evidenced in actual practice. By using proper mechanical means this extra cost of preparing the wood can be reduced one-third to one-half.

Fluted trunks may be used, since in preparing the wood for the "barkers," pulpwood bolts over 12 inches in diameter must be "sized" or split anyhow. Therefore, in splitting, the pieces may as well be separated on the "flutings" as elsewhere. The standard rossing machines then can easily remove all of the bark without excessive waste of good wood. That "limbiness" is not a serious objection is evidenced by the fact that many eastern mills now use wood from the tops of trees to as small a top diameter as 3 inches.

Cottonwood may be included in some of the Alaskan sales as a pulpwood, and it is locally considered to be suitable for no other use. The Alaskan cottonwood is of about the same character as cottonwood grown elsewhere.

All spruce and hemlock now considered merchantable for saw timber would make a high grade of pulpwood so far as defects are concerned. The proportions of timber merchantable for saw timber and of that merchantable for pulpwood but not for saw timber would, of course, vary in different stands, and this feature would be carefully studied in developing specific projects.

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SUITABILITY FOR PULP AND PAPER.

So far as suitability of species for pulp making is concerned, it should be sufficient to point to the British Columbia and Pacific Northwest pulp mills now operating on Sitka spruce and western hemlock. At times the hemlock alone is used, and it is said to prove as satisfactory as in mixture with quick-cook sulphite fiber, as far as quality of product is concerned. In addition to newsprint, only a few grades of building and mill wrapping paper are made at the British Columbia plants; but hemlock-spruce sulphite fiber is shipped to outside mills for the production of bond, manila, tissue, pure-fiber printing, and other high-grade papers requiring a strong, tough, white fiber.

Western hemlock and spruce are the standard mechanical and sulphite pulpwoods for the United States mills in the Pacific Northwest also, the hemlock being consumed in greater amounts than any other single species. In 1918, 145,583 cords of hemlock pulpwood and 35,385 cords of spruce was consumed in Washington, Oregon, and California. Of ground wood pulp the hemlock, mixed with spruce and cottonwood, amounts to 20 to 50 per cent of the total, and the yield for the mixed species is about 1,850 pounds of air-dry pulp per cord. Of pulp cooked by the sulphite process alone, the yield is about 1,050 pounds per cord. The spruce (75 per cent), mixed with black cottonwood (25 per cent), affords a yield per cord of about 950 to 1,000 pounds of bleached soda pulp suitable for the highest grades of book and writing papers made from wood. From these three woods the following papers are made: Manila, cartridge, express, bag, fiber wrappings, news, tissue, fruit wrap, toweling, sheathing, book, label, writing, and related papers.

The above facts show that the two principal species concerned are both commercially suitable for mechanical and sulphite pulps (including high-grade Mitscherlich fiber), and the papers that are usually made from them, as before specified.

While the consensus of practical opinion is that the spruce is somewhat the better pulpwood of the two, the following condensed summaries of some Forest Service semicommercial tests[6] at the Forest Products Laboratory, at Madison, Wis., carried on for a period of 10 years, afford a good opportunity for a comparison of them. The slightly greater weight of the hemlock per unit volume of prepared wood would usually be offset in commercial practice by the greater loss in cleaning. Yields are air-dry weight per cord containing 100 cubic feet of solid wood.

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[6] See "Paper," July 30, 1919.

Sitka Spruce—

Dry weight of wood per solid cubic foot, 24 pounds.

Average fiber length, 3.5 mm.

Sulphite pulp: Yield 1,080 pounds; easily bleached; easy pulped; excellent strength and color. Possible uses, similar to white spruce; is considered the standard for sulphite pulpwood and is used for news, wrapping, book, and high-grade printings, etc.

Sulphate pulp: Yield 1,150 pounds; easily pulped; excellent strength and color. Possible uses, similar to white spruce; highest grade of kraft paper and strong fiber board.

Mechanical pulp: Yield 2,040 pounds; character, slightly grayish color. Possible uses, similar to white spruce; for practically every use where ground wood pulp is required.

Western Hemlock—

Dry weight of wood per solid cubic foot, 23 pounds.

Average fiber length, 2.7 mm.

Sulphite pulp: Yield 1,050 pounds; easily bleached; easily pulped; good strength, fair color. Possible uses, similar to white spruce; is considered the standard for sulphite pulp wood and is used for news, wrapping, book, and high-grade printings, etc.

Sulphate pulp: Yield 1,100 pounds; character, good strong fiber. Possible uses, similar to white spruce; highest grade of kraft paper and strong fiber board.

Mechanical pulp: Yield 2,160 pounds; character, good strength and fiber; grayish color. Possible uses, similar to white spruce; for practically every use where ground wood pulp is required.

The Forest Service has little test data on black cottonwood, but from the resemblance this wood bears to other "poplars," and the results of its use in mixture by some of the western mills, it may be said with a fair degree of conservatism that this species will produce, with a medium yield per cord, a ground wood pulp of good white color, of short fiber, of little strength, soft, and free from pitch. It would serve as a filler for the finer grades of ground-wood papers when properly mixed with spruce ground wood and the long-fibered sulphate pulp.

There is every reason to believe that the Alaska cottonwood as a species would serve well as a source of soda pulp for high-grade book paper. The softness of the fiber would really be advantageous, and remnants of bark, knots, and fungous stain would be of no consequence in the soda process.

LOGGING.

The use of timber for commercial pulpwood in Alaska is just beginning. The 400,000,000 feet of timber sold and cut to date from the National Forests in Alaska has been made into products such as piling, sawlogs, and shingle bolts. The logging methods have been developed from "hand logging," in which the trees were felled so

that they would fall directly into the water or could be rolled in by hand, to steam-donkey logging, the donkey being mounted on a raft and "beached" at high tide, yarding directly into the water. Later two donkeys have been used, a yarder and a roader. In the water the logs are boomed and towed to the sawmills.

The logging heretofore has been of comparatively large or selected timber. Pulpwood cuts will have a larger yield per acre than those for other purposes, as smaller timber will be cut. It is doubtful if the present system of logging is the best and cheapest that can be devised for pulpwood logging on an extensive scale. An overhead system seems to promise one solution of the problem. In this system a number of small logs could be brought to the water with a "choker." Gravity chutes might be profitably employed on the steeper slopes. To reach the material farther back, it might be necessary to put in logging railroads running along the contour. No two logging units would present the same problem; several methods of logging would likely be used on the same general operation.

In 1918, $8.95 was the average cost for raw pulpwood at the mills in California, Oregon, and Washington. It is believed that pulpwood can be produced more cheaply in Alaska, as the greater part of the wood will be cut within less than a mile of the water's edge. Figures of $4 to $6 per cord would normally approximate average costs under present methods of logging.

The following cost figures are from "British Columbia, a Complete Guide," Vancouver, British Columbia, 1919:

Year.	Pulpwood. Cords.	Average value per cord.	Year.	Pulpwood. Cords.	Average value per cord.
1911	150	$7.60	1914	80,013	$5.33
1912	35,067	5.51	1915	90,535	6.08
1913	84,173	4.77	1916	108,997	5.32

The natural system of sheltered canals and waterways (see map, p. 40) and the proximity of most of the timber to them affords a great advantage in lessening the expense of logging. Log rafts are now towed as far as 200 miles to sawmills. Towage to the mill will be relatively inexpensive, especially if the operator uses his own tugs. It is estimated that the cost will not exceed 1 cent a mile per cord. This factor greatly reduces the original investment in logging plant, as compared, for example, with railroad operations. It also makes the physical factors in logging practically constant throughout a long period, as contrasted with the increasing cost of typical logging operations in the States, which must move farther and farther back into less accessible timber, with increasing cost of construction and operation as the rougher and higher country is penetrated.

The timber would be thoroughly soaked when delivered at the mills, but this would be of no disadvantage for ground wood pulp making except that logs left too long in salt-water storage would accumulate barnacles which it would be necessary to remove in cleaning the logs. In fresh-water storage these barnacles would doubtless drop off. It is probable that at a number of mill sites fresh-water storage would be obtainable. Soaked wood, although less desirable than fairly dry wood for sulphite pulp making, offers no great difficulty in this respect. A large number of American sulphite mills use wood coming directly from the water, and others have installed special chip driers. For making soda and sulphate pulp it is of much more importance that the wood be dry.

LABOR.

The local labor supply is adaptable to all kinds of work. Laborers are usually attracted from the woods to the canning industry, or to mining, or to the aquatic fur industry, depending on the wages paid and the conditions of employment. An assured supply of skilled labor would be available after a number of mills were established in the region, but there would, of course, always be competition from the other industries named.

It should be noted that there has been an exodus of white population from Alaska with the decline of the mining industry. It is estimated that not more than half of the 1910 population of 65,000 remains. However, the tendency to emigrate was checked in 1919, for during that year more people entered Alaska than departed from the Territory.

The Alaskan Engineering Commission, which is engaged in building a railroad from Seward to Fairbanks, imports its labor and maintains a crew of 3,000 to 4,000 men. This railroad will be completed in 1922, and competition for labor from this source will be eliminated.

It is of interest to note that laborers in Alaska are accustomed to work on a piece basis rather than on a time basis, and this would probably influence the employment of labor for logging operations. It might be desirable to consider contracting the labor for the cutting and delivery of pulpwood.

Many of the pulpwood operations in Alaska would not be located at or near towns already established. In order permanently to hold men in responsible positions under such circumstances, and to reduce the labor turnover to a minimum it would doubtless be necessary for the prospective operator to construct dwellings and to consider the extent to which he might provide such conveniences as stores and amusements to serve as inducements in securing and

retaining the full crew of laborers which is necessary for profitable operation. Social conditions would be almost entirely in the hands of the operator, and he would be guided by the trend of the times in respect to investments which are designed to secure the stability and efficiency of labor.

CONSTRUCTION OF IMPROVEMENTS.

"Construction from the ground up" summarizes the requirements to be met in Alaska, which is comparatively an undeveloped country. Following the acquisition of the timber and source of power, the mill site and town could then be advantageously located. It would be necessary to clear the site before construction could begin. A sawmill would no doubt be required, and the first logging would be for the clearing of a mill and town site, and the building of such necessary structures as wharves, storehouses, mills, dwelling houses, offices, machine shops, and stores. The power development might require the erection of a dam for storage purposes, in addition to the usual diversion works, conduits, water wheels, generators, and distributing system. Several of the structures would necessarily be of concrete. For logging, the improvements and equipment would depend on the methods employed. Scows, tugs, launches, pile drivers, and booms would be essential. During the period required for the construction and equipment of a pulp and paper mill in Alaska there would of course be no revenue.

OPERATING MATERIALS AND MILL SUPPLIES.

In addition to fuel, the more important operating supplies for pulp mills in general are lime or limestone, sulphur, soda ash, salt cake, grindstones, bleaching agents, and repair materials.

At present there are no operating limekilns in southeastern Alaska; one abandoned kiln in the Ketchikan district has been reported. A soda or a sulphate pulp mill could secure its lime by operating a kiln of its own, and there are numerous known deposits of limerock (marble) that would furnish high grades of lime (over 99 per cent CaO basis). Dolomitic limestone, however, is unknown in this region. It may be present, but no deposits have yet been located. Hence a sulphite mill requiring dolomitic lime would have to search for deposits of suitable rock or else import it from the "outside" at a high cost. By using the "tower system" of "acid" manufacture, however, a sulphite mill can employ high-calcium limestones, and British Columbia sulphite mills use this system. Such limestone is abundant among the sedimentary rocks of southeast Alaska. Belts of it miles in width are exposed on tidewater and

the rock can be quarried at small cost. The known deposits in Alaska of the high-calcium marble also could be made to serve very well for the tower system, and an enterprise could count on a cost delivered at something less than $1.50 per ton, the prewar price. The high-calcium lime should cost delivered something less than $5 per ton, the prewar price.

For sulphur, mills would have to depend on Japan or, more probably, on the Louisiana and Texas deposits. The cost delivered has been estimated at $22 per ton, the prewar price.

Soda ash and salt cake, delivered from San Francisco, cost about $27 and $17 per ton, respectively, the prewar prices. If electrolytic bleach were made, soda ash would be obtained as a by-product.

Undoubtedly the bleaching materials, if any are required, can be supplied most cheaply by operating an electrolytic process plant. The cost of salt for this purpose, delivered from San Francisco, is about $3 to $3.50 per ton, the prewar price.

Grinder stones would probably be shipped from the eastern United States or from England. With respect to Fourdrinier wires, machine clothing, machinery repair parts, belting, etc., the same would be true. A much larger stock of supplies and repair materials would have to be kept on hand than in the States. Any mill in Alaska would require extensive carpenter, smith, and machine shops of its own and, very likely, a foundry; otherwise, the only adequate shops and foundries to which the mill would have access would be those at Juneau or Prince Rupert.

DISPOSAL OF MILL EFFLUENTS.

As any mill in southeastern Alaska would be built on tidewater, and as the tidal variation is about 15 to 20 feet, there would be no difficulty in satisfactorily disposing of the effluents into the sea. On this account the mills of the region would have an advantage over the great majority of mills in the United States. Although no interference is anticipated with the salmon industry, this possibility should be carefully considered.

WATER SUPPLY.

Pulp and paper mills require comparatively large quantities of pure water. The character of the water supply, like the availability of the water power, can be determined only for the individual project. The peaty discoloration and the characteristic glacial turbidity of streams that are occasionally found may be corrected by means of a filter if necessary. For the ordinary grades of newsprint it might not be necessary to filter the water.

WATER POWER.

The following extracts from an article by J. G. Hoyt, Geological Survey Bulletin 442, indicate the general water-power situation in southeastern Alaska:

Owing to topography, the streams, with the exception of a few of the larger rivers which come through the mountains from the interior, have small and precipitous drainage areas. Their courses are short and they have a large fall; in fact many of the streams are made up of a series of cataracts.

In the northern part of the area most of the streams head in the glaciers which cover a large portion of the country. In the lower southern part of the area many of the streams head in small lakes which occur a short distance back from the shore line in the hanging valleys that are characteristic of this area. Most of the streams flowing from these lakes are precipitous and many of them empty into the ocean with a cataract at the shore line. These lakes afford excellent opportunities for storage, as the topography near them is such that a dam can usually be constructed for raising their water level. The most successful powers already developed depend on such storage during a large part of the year, and further development in this region will depend on the availability of such lakes.

The run-off from the streams in this area results principally from direct rainfall, melting snow, and melting glaciers. In view of the large rainfall, the excellent forest cover, and the glacial areas, the general deduction would be that this section should have many large streams with an abundant and well-sustained run-off. This, however, is not the case, as the catchment areas are small and, although the total yield per square mile is considerable, the streams are not large and they fluctuate very rapidly.

The streams which head in lakes have a much better sustained flow and are practically the only ones in the area which are of much value for power, as any large development must depend on storage, both for the winter months and during dry parts of the summer.

The principal defect in the water supply, so far as the production of power is concerned, is the extremely low flow during the winter months. On the smaller streams, which have no storage, there is practically no flow in winter, and even on the streams having lake storage the flow is extremely low, as shown in the records for Turner River, which empties into Taku Inlet near Juneau. This stream has a drainage area of 60 square miles and heads in Turner Lake, which offers excellent facilities for storage. A portion of the area is also covered with glaciers. The scantiness of the winter flow is due largely to the meager amount of storage capacity in the ground, which freezes to bed rock, thus holding back the water.

The winter flow is particularly slight when freezing weather comes before the heavy snowfall and in those inland locations at the head of inlets or passages where the ameliorating influence of the Japan Current is less effective. It has been estimated that on several sites, no storage being provided, the ratio of low winter flow (which involves two, three, or four months) to usual summer flow is only about 2 to 5 per cent. On the other hand, it should be noted that the high-flow period in Alaska coincides with the usual low-flow period in other locations which causes so many of the pulp mills to shut down in the late summer.

In developing the timber resources it will be possible to produce cheap steam power by the use of sawmill waste as fuel. The ultimate development, however, for both lumber and pulp will be through the establishment of mills at accessible power sites.

A great drawback to water-power development in this region is the difficulty of transmission. The country, as already stated, is cut by numerous channels, has a rough topography, and is covered with dense forests. Therefore transmission lines are difficult and expensive to construct, and this practically prohibits development at sites where the power can not be utilized at the point of development. In view of these difficulties, the possibilities at the present time for large power development in southeastern Alaska are not great, and such projects should be closely scrutinized as to their feasibility both from an engineer's standpoint and from that of an investor.

The opening of new mining districts and the development of the timber interests in this region will create a more widely distributed demand for power and enable the utilization of sites which at the present time can not be considered as available. As already stated, the success of any large water-power development, to be run during the entire year, will depend on the possibility of an adequate storage. The meager topographic data available indicate that there are probably many lakes throughout the region which will offer excellent storage facilities.

A number of power sites available for large-scale pulp and paper manufacture have been noted. In order to ascertain whether or not the powers on these sites will be fully satisfactory and how they can best be adapted, either alone or in conjunction with one another, definite surveys and other engineering investigations will be necessary, including stream-gauging through a period of years.[7] Of the specific powers noted, the more promising are those at Fish Creek, Shrimp Bay, Mill Creek, Warm Spring Bay, Speel River, Bailey Bay, Cascade Bay, Silver Bay, Swan Lake, Thomas Bay, Tease Lake, and Sweetheart Falls. The Warm Spring Bay, Mill Creek, and Speel River powers are known to receive glacial drainage and on this account are expected to be especially susceptible to temperature changes and to have wide extremes in summer and winter flow. This is known to be true of the Speel River powers, which have been gauged continuously throughout for several years.

There is no assurance that the powers mentioned above will be the best ones obtainable in southeastern Alaska. The country is so new and unexplored that no one now knows just what specific power possibilities may eventually be located. There are numerous known streams whose power head and summer flow would probably be satisfactory, and some of them may possibly have ideal sites for storage reservoirs sufficiently large to insure a sustained winter flow of 10,000 horsepower at a comparatively small cost; but until re-

[7] In the summer of 1915 the Forest Service established a number of stream-gauging stations in cooperation with the U. S. Geological Survey to ascertain the Alaskan power possibilities for pulp-manufacturing purposes. Twenty stream-gauging stations had been established in Alaska by 1917, and the records are being maintained. The data, including 1918, have been published as Bulletin 712–B of the Geological Survey.

cently no one has been interested in such sites, and casual knowledge of the region is not sufficient to locate them. However, the Forest Service is now conducting general reconnaissance work, and all prospective power and reservoir sites are being noted as the region is systematically cruised and mapped. In its administrative work also, efforts are continually being made to augment the existing information on power possibilities of interest to pulp and paper manufacturing enterprises.

WATER-POWER PERMITS.

The Federal water-power act (H. R. 3184) provides for the establishment of the Federal Power Commission, with offices in Washington, D. C., having authority to act in the administrative control of all power sites on the navigable waters and on the public lands and reservations of the United States, and over the location, design, construction, maintenance, and operation of power projects on such sites. Among the general duties assigned to the commission, the following are of immediate interest to those who are contemplating water-power developments: To issue preliminary permits for power projects; to issue licenses for power projects and transmission lines on navigable waters, public lands, and reservations of the United States; to prescribe rules for and to fix annual license charges; and to determine the relation of such charges to prices to consumers.

The Federal water power act applies to National Forests and provides a basis of charges as follows:

> That the licensee shall pay to the United States reasonable annual charges in an amount to be fixed by the commission for the purpose of reimbursing the United States for the costs of administration of this act; for recompensing it for the use, occupancy, and enjoyment of its lands or other property; and for the expropriation to the Government of excessive profits until the respective States shall make provision for preventing excessive profits or for the expropriation thereof to themselves or until the period of amortization as herein provided is reached, and in fixing such charges the commission shall seek to avoid increasing the price to consumers of power by such charges.

The passage of this act gives stimulus to water-power development which has been handicapped in the past, largely on account of the uncertainty of tenure under the old law. The legislation provides for the issuance at reasonable rates of term licenses, which will be irrevocable except for violation of their terms.

DEVELOPED WATER POWER IN ALASKA.

About 15 water-power projects, developing a total of 37,350 horsepower, were reported in 1917 for the region of southeastern Alaska. These plants furnish power for mining and various other industries. The largest plant in southeastern Alaska develops 5,700 horsepower.

FUEL.

Fuel for steam power can be obtained from three main sources:

(1) Wood waste from logging, pulp mill, wood room, and sawmill operations.

(2) Coal now delivered by colliers from the Vancouver Island mines and from the Alaska fields of coal and lignite when they have been developed.

(3) Fuel oil delivered in tank steamers from the California fields.

MARKETS.

The leading market for pulp and paper from the Tongass National Forest will be the United States. Its transition in 10 years from the position of an exporter of newsprint to that of an importer, securing two-thirds of its supply abroad subject to any restriction which it may be to the interest of the exporter to impose, will make it advantageous to paper users to patronize the manufacturers of Alaskan pulpwood. The successful installation of pulp and paper plants in British Columbia after a number of trials has proved that the exploitation of this general region is practicable. They represent a logical, progressive exploitation of known proportions. The conditions of acquirement of timber in British Columbia are no more advantageous than those in Alaska, nor are they likely to become so.

In 1919 the pulp and paper mills of British Columbia produced 120,000 tons of paper (mostly newsprint) and 170,000 tons of pulp (ground wood, sulphite, and sulphate).[8] Their principal markets are the Pacific coast States of the United States, the western Provinces of Canada, Japan, Australia, and New Zealand.

The product of Alaskan mills will come into direct competition in markets now supplied by Canadian and American mills. By reason of the accessibility of timber to the Alaskan mills and favorable operating conditions, this competition should be successfully met. Manufactures in British Columbia and Alaska have little to fear from each other and much to gain in the common development of the region.

Norwegian paper was formerly shipped to Seattle and the west coast, South America, and the Orient. Because of the disadvantages they suffer as to fuel supply and raw materials European producers are likely to be supplanted in many markets by west coast mills.

The largest potential market in the Orient for the Alaskan producer is China. The annual per capita consumption there is less than one-quarter of a pound. The per capita consumption of the United States is 33 pounds per annum of newsprint alone, or 100

[8] Pulp and Paper Magazine of Canada, Jan. 15, 1920.

pounds per capita of all papers. If the market in China were developed to one-tenth that of the United States the demand would be enormous.

The unique advantages in the exploitation of Alaskan timber are the proximity of raw materials to tidewater and natural power sites and the favorable relation to the world's markets. Obviously, a paper plant located in southeastern Alaska has a world-wide choice of markets under independent transportation conditions, either rail or water transportation being available.

TAXES.

Outside of incorporated towns no general property taxes are imposed, but all industries in Alaska, including those in incorporated towns, pay a Federal license fee which, where applicable, is based on actual yearly output. No license fees have been named to date on pulp and paper, but it is reasonable to suppose that this will be done when the industry becomes established. The fee on lumber is 10 cents per thousand feet b. m.

FREIGHT RATES.

In the absence of cargoes for shipment, it is difficult to get firm quotations as to costs of transportation. Any rate quoted would probably be above a competitive rate which could be obtained on cargo shipments. In 1914 the rates were about $2 per marine ton (40 cubic feet) from points in the vicinity of Ketchikan to Portland and Seattle. The rate from Juneau and vicinity was about $3 per marine ton. These rates have more than doubled for the class of merchandise included in the classification. However, there is no reason why an enterprise with the tonnage of an ordinary-sized newsprint mill should not operate its own or chartered ships so that the above rates would be approximated under conditions similar to those of the present time, especially if the return cargo were charged with its share of the expense.

In this connection it is interesting to note that the exports far exceed the imports of Alaska. The balance of trade in favor of Alaska is about $30,000,000 per annum. A result of this is, of course, that there is greater demand for cargo space for outbound than inbound traffic, and an explanation is afforded in a measure of the fact that coal is shipped into southeastern Alaska from Vancouver rather than from the fields along the Government railroad terminating at Seward.

In 1917 the rates on dry pulp in bales from Seattle to the Orient were about $5.50 per 2,000-pound ton; on newsprint, $6 to $7. On paper of any kind the rates to Australia were $5.50 to $8. These

rates have been increased since 1917. In 1915 the all-water rate quoted on general cargo from coast to coast was $8 per 2,000 pounds. In 1920 the Shipping Board quoted a rate of 90 cents per hundred from the Pacific to the Atlantic via the Panama Canal. This is $18 per ton. It is understood that the rail rate from Seattle to New York is about $24 per ton for newsprint. At the present prices for newsprint, this charge of one and a fraction cents per pound is not prohibitive; and, in view of the shorter time required than for water transportation, it may be favorably considered.

It is believed that shipping by rail from Prince Rupert will before long become a factor of importance. It is probable that pulp and paper shipments at very favorable rates via American-owned boats will be made in scow loads to Prince Rupert, and possibly by car ferry, to save handling and export packing. Prince Rupert also may in the future offer facilities for transshipment to coast and transocean ports. It has been estimated that shipment by scow from points in southeastern Alaska to Prince Rupert would cost 50 cents to $1 per ton.

The following statement concerning transportation by the Grand Trunk Pacific Railway was furnished under date of July 7, 1920, by A. E. Rosevear, general freight agent of that railway, in response to an inquiry from the Forest Service:

The present freight rates of wood pulp, sulphite, or sulphate (wet or dry), in rolls or compressed in bales, carloads, from Prince Rupert, British Columbia, to Minneapolis, St. Paul, Minnesota Transfer, Duluth, and other similar eastern United States terminals, is 56½ cents per 100 pounds; to Chicago, 69 cents; and to New York, 92½ cents; minimum weight, 60,000 pounds per car. (Since the above was written a 35 per cent increase in freight rates has been made effective.)

On news-print paper, carloads, also on wrapping paper (not printed) the present rates from Prince Rupert, British Columbia, are, to Minneapolis, St. Paul, Minnesota Transfer, Duluth, and other eastern United States terminals, as well as to Chicago and New York, $1.06½ per 100 pounds; minimum weight, 40,000 pounds per car.

The main line of the Grand Trunk Pacific Railway extends from Prince Rupert, British Columbia, to Winnipeg, Manitoba, distance, 1,748 miles. At Winnipeg it connects with the Great Northern Railway, Northern Pacific Railway, through the Midland Railway of Manitoba, also with the Canadian Pacific Railway in connection with their Soo line, as well as with the Canadian National Railways.

The grades from Prince Rupert easterly through the mountains are four-tenths of 1 per cent, with the exception of 20.15 miles of 1 per cent grade, designed for operation as a pusher grade. In effect, therefore, the Grand Trunk Pacific Railway grade against eastbound traffic is virtually four-tenths of 1 per cent as against westbound traffic an actual four-tenths of 1 per cent.

There is but one summit through the mountains of British Columbia, and this has an altitude of 3,724 feet above sea level. There are 7 short snow sheds and 11 short tunnels west of the Rockies on the way to Prince Rupert. Less

snow is experienced on the line of the Grand Trunk Pacific Railway through the mountains than on any other northern Pacific coast line, which includes the Chicago, Milwaukee & St. Paul, Great Northern, Northern Pacific, and Canadian Pacific Railways.

At Prince Rupert, British Columbia, the railway recently installed a car-ferry slip dock, and a similar slip dock has been installed at Swanson Bay, British Columbia, by the Whalen Pulp & Paper Co., in order to cater to the loading and unloading of carload traffic at Swanson Bay, thus avoiding the expense and delay occasioned by steamer service and transfer of shipments at Prince Rupert from or into cars. The distance from Prince Rupert to Swanson Bay is 112 miles.

The installation of a car-ferry slip dock at Ketchikan, Alaska, could, we understand, be easily accomplished, and navigation would be safe between that point and Prince Rupert, British Columbia, a distance of 93 miles. The channel between Prince Rupert and Ketchikan is protected practically all the way by islands, which form a natural breakwater, thus insuring safe operation of a car ferry; and the same remarks apply with equal force to other points in southeastern Alaska, such as Prince of Wales Island, Wrangell, Petersburg, Treadwell, Douglas, Juneau, Haines, and Skagway, including intermediate points.

In answer to your question as to whether a car-ferry service appeals to us as feasible under present conditions, we beg to reply in the affirmative, provided slip-dock facilities are installed and such industries located and in operation as to make it an object to the railway to inaugurate the service.

PROCEDURE IN GOVERNMENT TIMBER SALES.

National Forest timber is examined and, if its sale is desirable, it is estimated and appraised by a forest officer. It is then advertised at a minimum stumpage rate or rates, the highest bid (sealed) accompanied by the required deposit from a responsible party is accepted, and the award is made on condition of the execution of a satisfactory contract and the delivery of a sufficient bond. Required deposits are made as cutting continues, and at stated intervals the timber is reappraised and new rates fixed in accordance with the terms of the contract. The local forest officer in charge scales or measures the timber, requires the deposit of funds, and represents the Service in the enforcement of the contract.

The United States Forester is represented by the district forester and forest supervisors, who are in a position to explain in detail all the requirements as to organization, financial showing, and conditions of sale.

It should be understood that timber is sold by the Forest Service only for continuous operation, and that the general policy or form of contract does not permit the acquirement of timber on a speculative basis. The Forest Service recognizes the difficulty in promoting an enterprise of the magnitude of a pulp or paper mill in Alaska, and gladly gives assistance and data to the extent of its resources, but declines to enter into a sales contract before it is assured of the

financial ability of the applicants to operate according to the terms of the contract.

The Forest Service sells stumpage only. The purchaser of timber has no cut-over land problem, for the Government retains title to the land. Any legitimate use of the land incident to the development of the project is allowed at a nominal consideration or free of charge.

AUTHORITY TO SELL TIMBER.

The act of June 4, 1897 (30 Stat., 11), authorizes the sale of timber on the National Forests. It also permits the export of any forest product from Alaska (see any agricultural appropriation bill, and the act of February 1, 1905 (33 Stat., 628), and this permission includes, of course, the export of pulpwood and wood pulp. The act of May 14, 1898 (30 Stat., 414), prohibiting the export of timber from Alaska does not apply to National Forests. The fact that these two sections appear in the codified laws of Alaska as sections 226 and 100, respectively, without any cross reference whatever, has confused many in their search for legal authority for the exportation of timber, and on reading section 100 they have assumed such exportation was illegal.

Timber can not be legally acquired under the mining law, nor is there any provision for purchases of timberland or concessions of timber. The disposition of the timber is, as has been indicated, on a competitive bidding basis by sealed bids.

POLICY.

The policy under which the Forest Service is now working, with respect to the development of Alaskan timber resources for pulpwood, is as follows:

(1) Firm contracts are offered for sufficient timber to supply a proposed paper mill for as much as 30 years; and, if additional timber is available, which may properly be reserved from other present disposition, the Service offers as one of its contract stipulations to reserve additional stumpage from sale up to a maximum of 15 years' supply pending the completion of the first contract, and thereupon to appraise the reserved area and place it upon the market. The maximum amount of timber the Forest Service is prepared to award to one purchaser or group of interests is two billion feet board measure or its equivalent in cubic feet.

(2) The contracts provide for the reappraisal of stumpage prices at intervals of five years after timber cutting begins, the first to be made seven years after the contract is signed if the full two-year period allowed for construction is used for that purpose; but, in addition to fixing the price for the first five years, a scale of prices is named which will in no event be exceeded in the reappraisal cover-

ing the second five-year period. The possible maximum prices for the second five-year period are ordinarily double the rates fixed for the initial period. The purpose of this provision is to fix a maximum liability for the cost of timber during the first 10 years of operation of the enterprise. After the first and most critical 10 years in the life of a new enterprise of this character, reappraisals are to be without this special limitation, but must be within the average current price obtained for corresponding timber in southeastern Alaska.

(3) The reappraised rates in pulpwood contracts are based upon the current value of corresponding timber in southeastern Alaska, full recognition being given in reappraisal to the quality and accessibility of the timber included in the particular contract and to any other physical condition affecting the operations of the purchaser.

STUMPAGE PRICES AND READJUSTMENTS.

Minimum stumpage prices for each sale are on the basis of appraisals worked out under standard methods which are applied to each unit of timber before advertisement by the Forest Service. A tract of pulpwood has recently been advertised and sale awarded on the Tongass Forest near Port Snettisham at rates of $1 per thousand for spruce, cedar, and cypress, and 50 cents per thousand for hemlock and cottonwood.

The stumpage prices in Alaska have varied recently from 50 cents to $3 per thousand feet, board measure, depending on the species, quality, and condition of the timber, its accessibility to tidewater, the cost of logging, etc. The appraisals are made on the basis of immediate operation, and provision is made, as hereafter explained, for reappraisal of timber under long-term contracts.

The sample contract, a copy of which is included in this bulletin, provides for a readjustment of stumpage prices after the first five years of operation following the two-year period of construction, and at five-year intervals thereafter during the life of the sale. In addition to fixing the price for the first five years, a scale of prices is named which will in no event be exceeded in the reappraisal covering the second five-year period. The readjusted rates will in no event exceed the arithmetical average price received for stumpage in the National Forest sales during the preceding 12 months from the National Forests of Alaska. The reappraisals will be based, according to contractual obligations, on the price of logs of similar species in southeastern Alaska, on the current operating costs in southeastern Alaska, and on a reasonable margin for profit and risk in the business of logging.

The general principle of the redetermination of stumpage prices during the life of long-term timber sales has been in effect on all

National Forests for many years, but the interval between reappraisal dates of saw timber sales in the States is usually three years. Pulpwood contracts in Alaska provide that these reappraisals shall be made by determining the current value of corresponding timber, due weight being given to the quality and accessibility of the stumpage and other physical factors in the particular operation. The reappraisal plan has proved to be reasonable and fair both in principle and in application, as is evidenced by the fact that, while provision is made for an appeal to the Secretary of Agriculture from the decision of the United States Forester in fixing reappraised stumpage rates, no appeal has as yet been received. The good faith of the Forest Service has never been questioned in its reappraisal work. It is as willing and able to satisfy operators for pulpwood in Alaska as it is to satisfy operators for saw logs, pulpwood, or other materials on the National Forests in Idaho or California.

The principle of reappraisal at intervals during the life of a long-term contract for the purchase of timber from a National Forest is essential as a means of preventing speculation in Government property. Without it there would be at least an opportunity for a purchaser to have his chief interest not in a bona fide manufacturing enterprise, but rather in the chances for disposing of his contract to his own pecuniary advantage. The effect of the establishment of such a speculative system would be disastrous so far as it concerns the actual development of such industries as the manufacture of pulp and paper in Alaska. Furthermore, wholly aside from the principle that the public is entitled to a fair return for its property, the intent of the law is that National Forest timber shall be sold at not less than its market value. It is the manifest duty of the Forest Service to secure such returns from long-term as well as short-term sales.

In many respects this principle of reappraisal works to the advantage rather than to the disadvantage of the purchaser. Under Forest Service timber-sale contracts a purchaser pays for timber in relatively small amounts prior to cutting. At no time during the life of the sale is it necessary for him to make a heavy investment in standing timber. In order to justify the establishment of a new pulp and paper mill, backed by privately owned timber, a heavy initial investment in timberlands would be necessary, and this investment would be steadily increased by interest charges, taxes, and protection costs. On the Pacific coast it is customary for timberland owners to consider that their investment in standing timber doubles every 8 or 10 years. This is a fixed charge which can not be avoided. A purchaser of National Forest stumpage, however, has no such inevitable increase in the cost of his raw material, for each reappraisal merely determines the actual current value of the

stumpage. Money paid for stumpage is returned to the manufacturer in a few months, as he markets his product. The price fixed by these reappraisals may be more or may be less than the cost of similar private stumpage bought at the beginning of the sale and carried to the same time, with the increases due to interest charges, taxes, and protection. The stumpage cost of privately owned timber necessary as a backing for a pulp and paper mill would increase at a constantly accelerating rate per unit of volume because of the compounding of interest. The influence of this factor is so strong as to make the purchase of National Forest stumpage, to be paid for practically as cut and at its actual current value, preferable from a strictly business standpoint. In fact, this principle of reappraisal at intervals during the life of the contract has been accepted as reasonable and satisfactory by applicants who are now negotiating with the Forest Service for pulpwood in Alaska.

STUMPAGE PRICE READJUSTMENTS IN CANADA.

The principle that the public is entitled to the price increment on the value of its property is recognized in the various forms of pulp licenses and sales in British Columbia, Ontario, Quebec, New Brunswick, and Nova Scotia. In each Province the timber acquired by individuals is subject to a "royalty," which is increased by "orders in council." This right to increase the royalty is equivalent to the right to readjust prices on stumpage in the Forest Service contracts, and is freely exercised in the Canadian Provinces wherever it is deemed necessary. In some Provinces the change is possible only at certain stated intervals.

FINANCIAL STANDING OF PURCHASERS.

The objects of the financial requirements are: (1) To secure as purchasers bona fide operators having adequate financial assets to carry out sale contracts successfully, and (2) to eliminate speculators and promoters who risk no capital of their own, have little permanent interest in the success of the enterprise, and seek profits primarily from the formation of a new company or the manipulation of its stock.

These requirements will not be so enforced as to prevent legitimate promotion or the financing of National Forest sales in part with borrowed capital by responsible men in accordance with conservative business standards. Evidence as to financial standing will be required before advertised timber is finally awarded and the contract furnished to the successful bidder for execution. Information as to required assets will be given in response to inquiries at the time timber is being advertised, in order that the prospective bidder may be informed as to the showing required.

AMOUNT OF CAPITAL REQUIRED.

The production of pulp and paper is always in large units, on account of the extensive investment for the developments which must be made for power, manufacture, transportation, and other facilities. Roughly, the capital required for manufacturing a given amount of stumpage into paper is thirty to forty times greater than that for manufacturing it into lumber. In 1916 the cost of a pulp and paper plant was figured by the Forest Service at $25,000 per ton for a balanced ground-wood sulphite and paper plant producing 75 tons per day. The same plant to-day would probably cost $4,000,000. The trade paper, Pulp and Paper Magazine, of Canada, for January 15, 1920, cited two proposed developments. One requires a capital of $5,000,000 to build a plant covering 100 acres with an annual capacity of 75,000 tons of sulphite pulp and 35,000 tons of newsprint. Twelve thousand horsepower are required. Another plant with a 200-ton daily capacity of sulphite pulp and a ground-wood mill with a daily capacity of 200 tons of newsprint calls for an outlay of $5,000,000 to $6,000,000. There is likely to be great divergence in costs of plants of similar capacity in Alaska, depending on the cost of power development and the inherent conditions of the site.

The careful investigation of various sites by a competent engineer is necessary for the proper correlation of initial costs as against costs of operation. A prospective purchaser will, of course, make his own investigations of all essential features. One applicant is known to have spent more than twenty-five thousand dollars through several experts in investigations of pulp timber, water power, and general conditions before making formal applications for timber or water power.

APPLICATIONS FOR TIMBER AND WATER POWER.

There is no prescribed form of application for timber, and no priority is established by the filing of an application, for the award is based on the acceptance of the highest satisfactory bid. An application filed with the Forest Service furnishes a basis for the determination as to whether the timber is for sale and, if the application is from responsible parties, for the examination and advertisement of the timber. Definite statements as to the requirements, plans, resources, and tentative organization of the applicant are very desirable as an aid to the Service in considering applications. Applications should preferably be made to the district forester, Forest Service, Ketchikan, Alaska (Juneau, Alaska, after July 1, 1921), although they may be made through the district forester, Forest Service, Portland, Oreg., or the Forester, Forest Service, Washington, D. C. Applications for water power should be made to the Federal Power Commission, Washington, D. C.

TIME REQUIRED TO SECURE CONTRACT.

No definite statement can be made as to the length of time required to consummate a pulp-wood contract. The timber will ordinarily be advertised for at least three months. Prior to advertisement, however, the prospective purchaser must of necessity make his own expert determination of the desirability and practicability of the project. If the examiners will keep in touch with the local representatives of the Forest Service, it will usually be possible for the Service to get the timber desired in shape for advertisement and sale by the time the examinations of the company are completed and the company is ready to proceed with the development.

REFERENCES.

For the convenience of those who desire references to the literature of the industry, the following suggestions are given:

Bibliography of the Pulp and Paper Industries, by Henry E. Surface, Forest Service Bulletin No. 123. This bulletin gives a comprehensive summary of the literature up to 1913, with a list of pulp and paper trade papers, and is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 10 cents.

The rules and regulations governing National Forests, together with the procedure in timber sales, special uses, and other activities of the Forest Service, are given in The Use Book, which may be had on application to the Forest Service.

Alaskan conditions are well set forth in the annual reports of the governor of Alaska to the Secretary of the Interior. A list of references is given in these reports also to Government publications on Alaska.

Lists of manufacturers of pulp and paper mill machinery and supplies are given in Thomas's Directory of American Manufacturers.

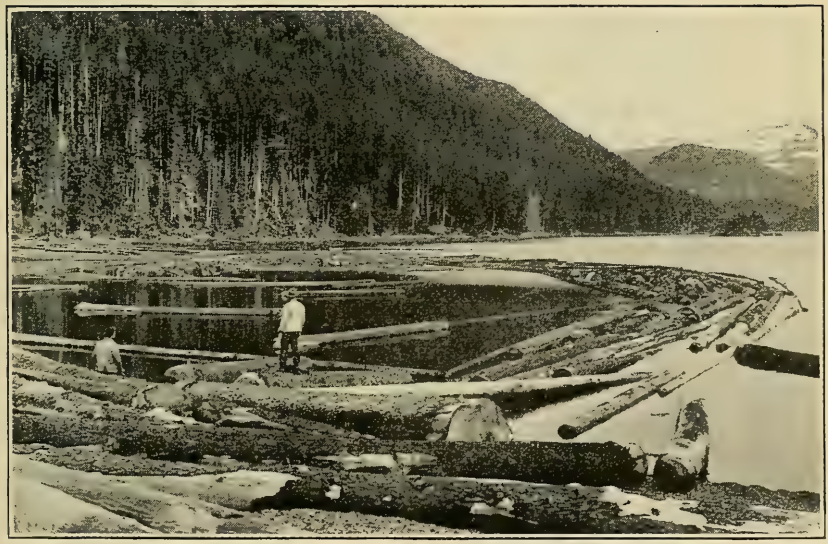
MAPS AND SURVEYS.

It should be understood that, although general statements of location and stand of pulpwood are given to show the sufficiency of timber for regional development, the statements are not sufficiently detailed for the segregation of pulpwood stands into operative units, properly correlated to water power and other facilities, without an independent examination and determination on the part of the prospective purchaser. When he is satisfied as to the opportunities the Forest Service will offer the timber for sale after a rough reconnaissance has been made.

The map attached shows the best present information the Forest Service has as to the location of water power and desirable pulp

F-24498A

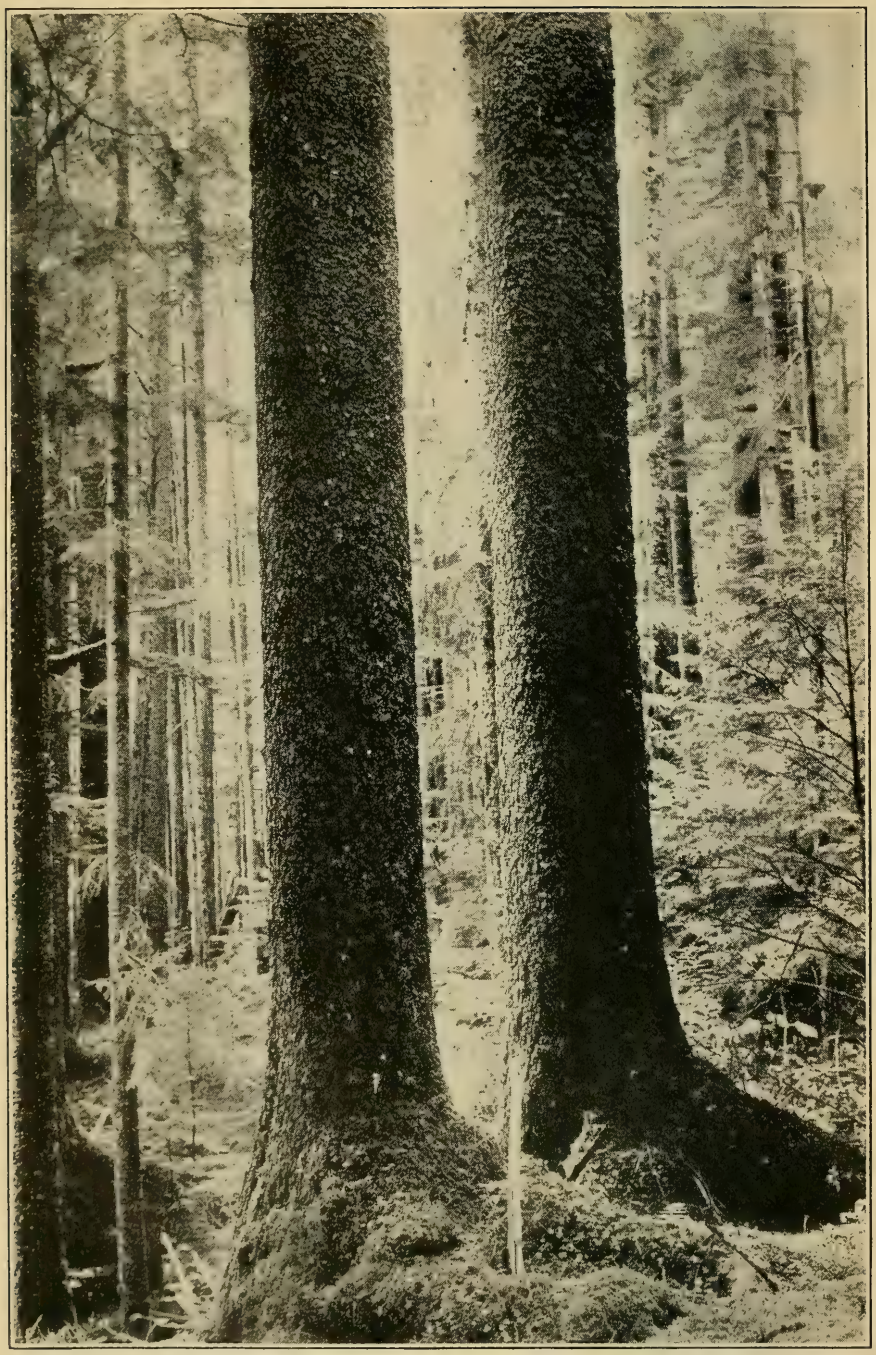
FIG. 1.—FOREST OF HEMLOCK, SPRUCE, AND OTHER SPECIES NEAR KETCHIKAN, ALASKA.



F-73999

FIG. 2.—LOGS CUT UNDER A FOREST SERVICE TIMBER-SALE AGREEMENT AND HELD IN A BOOM AWAITING TOWAGE TO MILL, WHITEWATER BAY, ADMIRALTY ISLAND.

TONGASS NATIONAL FOREST, ALASKA.



F-70500

A PAIR OF BEAUTIES—SITKA SPRUCE. THE TREE ON THE LEFT MEASURES 37 INCHES AND THE ONE ON THE RIGHT 39 INCHES IN DIAMETER.

The clearer portions of trees like these may profitably be cut into high grade-lumber. The smaller timber in the background contains much valuable pulpwood material.

units. It has been the object to allocate roughly to each water power an amount of timber properly situated to keep it in operation continuously. The Forest Service is not committed, however, to the sale of timber on the units as delineated. The map may serve as a guide for the examination of suitable locations, and no more. The Service has available on request maps of the Tongass Forest, drawn on a scale of 8 miles to the inch, which give more particulars and would be valuable in the detailed examination of pulpwood resources.

The Service has had insufficient funds to conduct intensive surveys and stream-gauging work on the Tongass Forest on a satisfactory scale, but is pushing this work as rapidly as its resources permit.

The coast line of Alaska is being charted by the United States Coast and Geodetic Survey. The charts produced are satisfactory for navigation. These maps furnish a basis for the survey of the interior, which has been partially mapped by the United States Geological Survey, the Land Office, and the Forest Service. The area indicated on the map as having been cruised does not comprise the entire area surveyed by the Service. Detached surveys are made in connection with numerous special uses, timber sales, homestead-land settlement, improvements, etc. However, the survey of an area of 20,000,000 acres with a coast line of 12,000 miles is obviously a task which it will take years to advance to a point where reasonable demands for maps and estimates of timber can be satisfied.

(Sample agreement.)

UNITED STATES DEPARTMENT OF AGRICULTURE.

FOREST SERVICE.

TIMBER-SALE AGREEMENT.

DESCRIPTION OF TIMBER.

Sales, D–6, Tongass (pulpwood).

SEC. 1. We, _____ a corporation organized and existing under the laws of the State of _____, having an office and principal place of business at _____ State of _____, hereby agree to purchase an area of about _____ acres to be definitely designated on the ground by a Forest officer prior to cutting, on _____ _____ as definitely designated on the attached map which is hereby made a part of this agreement, within the Tongass National Forest, at the rate or rates, and in strict conformity with all and singular the requirements and conditions hereinafter set forth, all the dead timber standing or down and all the live timber marked or designated for cutting by a Forest officer, merchantable as hereinafter defined, for pulpwood, saw logs, and for other forest products

Area and location.

customarily produced in Alaska. The estimated amount to be cut under the provisions of sections 7 and 8 is

Amount.

_____ cubic feet of Sitka spruce, hemlock, and other species, approximately _____ per cent Sitka spruce and _____ per cent hemlock.

Provided, That in designating the area to be cut and the areas to be reserved from sale as specified in section 2(h) herein, units, bearing timber suitable for local use may be excluded to a total amount not exceeding _____ cubic feet or equivalent amount in other units of measure if, in the judgment of the forest supervisor, the operation of the purchaser is not interfered with thereby.

Provided further, That the purchaser shall establish in Alaska, not later than _____, a pulp manufac-
(Date)
turing plant or plants with a daily capacity of not less than _____ tons, which daily capacity shall be increased, not later than _____, to a
(Date)
total of at least _____ tons. Failure of the purchaser to make the first installation by the date first above specified shall render this agreement subject to cancellation in the discretion of the Forester; and failure to increase the daily capacity of the plant or plants by the second date above specified will render this agreement subject to such a reduction in area and volume of timber as will be, in the judgment of the Forester, commensurate with the manufacturing capacity established.

PAYMENTS.

Initial rates.

SEC. 2 (*a*) We do hereby, in consideration of the sale of this timber to us, promise to pay to the First National Bank of Juneau, Alaska (United States depository), or such other depository or officer as shall hereafter be designated, to be placed to the credit of the United States, for the timber at the following rates:

Reappraisals.

For all timber cut prior to April 1, 1928, at the following rates:

$_____ per 100 cubic feet for Sitka spruce and Alaska cedar, and

$_____ per 100 cubic feet for hemlock and other species.

For all timber cut on or after April 1, 1928, and prior to April 1, 1933, at such rates as shall be designated by the Forester within thirty days preceding April 1, 1928;

For all timber cut on or after April 1, 1933, and prior to April 1, 1938, at such rates as shall be designated by the Forester within thirty days preceding April 1, 1933;

For all timber cut on or after April 1, 1938, and prior to April 1, 1943, at such rates as shall be designated by the Forester within thirty days preceding April 1, 1938;

For all timber cut on or after April 1, 1943, and prior to April 1, 1948, at such rates as shall be designated by the Forester within thirty days preceding April 1, 1943;

And for all timber cut on or after April 1, 1948, at such rates as shall be designated by the Forester within thirty days preceding that date.

Except as hereinafter provided, material below merchantable size under the terms of this agreement which is cut and removed at the option of the purchaser shall be paid for at the rates then in effect for merchantable material. Material unmerchantable on account of defects may be removed without charge in the discretion of the district forester.

(*b*) The Forester shall reappraise and within thirty days before each of the foregoing dates designate the value of each species in consideration of current operating conditions and markets in southeastern Alaska, including the operation of the purchaser, such reappraisals to include the timber on the entire tract, and to be based upon an equitable margin for profit and risk to the purchaser under the operating conditions prevailing throughout the region: *Provided*, That the stumpage price for any species fixed upon any reappraisal date shall not exceed the arithmetical average of the prices received for National Forest stumpage of that species in southeastern Alaska during the twelve months preceding the date of reappraisal, as shown by sale contracts executed during that period; and

Provided further, That in no event shall the stumpage price for any species established by the Forester to apply during the period from April 1, 1928, to April 1, 1933, exceed double the initial rate for that species as stated above.

(*c*) If any material cut under this agreement and merchantable under its terms is manufactured or sold by the purchaser for other uses than pulp or its products, the Forester may upon the next reapparisal date establish a special stumpage rate for each class of material so manufactured or sold during the succeeding period, which rate, in accordance with the ratio per one hundred cubic feet currently used by the Forest Service, shall be not less than the initial stumpage price fixed herein and shall allow the purchaser an equitable margin for profit and risk under current selling prices and costs of production in the region defined above.

(*d*) It is further agreed that the Secretary of Agriculture will, upon written application from the purchaser showing good and sufficient reasons therefor and specifically the existence of a serious emergency arising from changes in market conditions since the last reappraisal, at his option, when action of either character is necessary to relieve the purchaser from hardship, either—

(1) Redetermine and establish the stumpage rates and designate a date when the rates as redetermined shall be effective, which date shall be within six (6) months of the date of application, or

(2) Grant an extension of time within which the respective amounts of timber specified in section 4 shall be removed, not to exceed the total period allowed for cutting all the timber.

Any stumpage rates redetermined upon application to the Secretary shall be determined in accordance with the methods and under the terms above set forth, and shall apply only during the remainder of the five-year period then current, when the rates shall be regularly designated after reappraisal.

(*e*) In no event, however, shall the stumpage rates for products from material whose utilization is required by this agreement as established upon any date above named, or upon application from the purchaser, be less than those specified herein to be paid for timber cut prior to April 1, 1928.

(*f*) It is further agreed that at the date of any reappraisal of stumpage prices the Forester may require such modifications in the sections numbered 7, 8, 13, 15, 16, 17, 18, 19, 21, 22, 23, and 24 in this agreement as are necessary, in his judgment, to protect the interests of the United States. Such modifications shall be limited to requirements contained in the then current timber sale contracts in southeastern Alaska and shall be practicable under the existing equipment and organization of the purchaser. Any additional operating costs entailed by such modifications, as ascertained by the Forester, shall be taken into consideration as a factor in reappraisals.

(*g*) Payments shall be made in advance installments of not less than ten thousand dollars ($10,000) and not more than twenty thousand dollars ($20,000) each when called for by the Forest officer in charge, except just before the completion of the sale or a period when cutting operations are to be suspended for at least three (3) months, when the amount of the payment shall be designated in writing by the Forest supervisor, credit being given for the sums, if any, heretofore deposited with the said United States depository or officer in connection with the sale.

(*h*) It is further agreed that an area or areas of timber located on the Tongass National Forest located_____ _____ which areas are considered by the district forester to be accessible to the manufacturing plant of the purchaser, shall be later selected and cruised by the Forest Service. These areas shall, except in case of serious deterioration from fire, insects, or similar causes, be reserved from sale by the United States until six months prior to the completion of cutting on the area covered by this agreement, but in no event later than October 1, 1952, and it is agreed that at a date so determined the timber on the areas to be selected, together with any timber included in this agreement which in the judgment of the district forester will be uncut on March 30, 1953, shall be appraised and advertised for purchase under sealed bids, at such minimum prices and under such conditions and requirements as the Forester shall deem necessary: *Provided*, that the total amount of timber included under this agreement and on the areas to be selected shall approximate but not exceed_____ cubic feet, which amount is not guaranteed by the United States.

PERIOD OF CONTRACT.

Cutting period.

SEC. 3. The cutting and removal of timber under this agreement shall begin not later than April 1, 1923, and unless extension of time is granted all timber shall be cut and removed and the requirements of this agreement satisfied on or before March 30, 1953.

Periodic cuts.

SEC. 4. Unless such amounts are reduced in writing by the district forester at least _____ cubic feet

shall be cut prior to April 1, 1928; at least _____ _____ cubic feet shall be cut prior to April 1, 1933; at least _____ cubic feet shall be cut prior to April 1, 1938; at least _____ cubic feet shall be cut prior to April 1, 1943; and at least _____ _____ cubic feet shall be cut prior to April 1, 1948.

TITLE.

Title to timber.

SEC. 5. The title to all timber included in this agreement shall remain in the United States until it has been paid for, and scaled, measured, or counted as herein provided.

Timber on claims.

SEC. 6. Timber upon valid claims and all timber to which there exists valid claim under contract with the Forest Service is exempted from this sale.

DESIGNATION.

Timber reserved in marking.

SEC. 7. Timber shall be designated for cutting as follows: The exterior boundaries of the sale area shall be marked and all seed trees and groups of seed trees and areas considered unmerchantable or inaccessible in the judgment of the Forest officer in charge within these boundaries shall be plainly marked or posted. All other timber shall be considered as designated for cutting. Groups of trees or single trees may be reserved for seed wherever it may be deemed necessary by the Forest officer in charge: *Provided*, That not more than five per cent (5%) of the mechantable volume on the sale area shall be so reserved. All other merchantable timber shall be cut.

Minimum diameter limits.

SEC. 8. The approximate minimum diameter limits outside bark at a point 4½ feet from the ground to which timber shall be designated for cutting under the terms of this agreement are fourteen (14) inches for Alaska cedar and eight (8) inches for all other species.

LOGGING.

Plan of logging operations.

SEC. 9. As far as may be deemed necessary for the protection of national forest interests, the plan of logging operations on the respective portions of the sale area shall be approved by the Forest officer in charge. When operations are begun on any natural logging area, the cutting on that area shall be fully completed to the satisfaction of the Forest officer in charge before cutting may begin on other areas, unless such cutting is authorized in writing with the requirement that cutting shall be completed on the area left unfinished as soon as practicable. After decision in writing by the Forest officer in charge that the purchaser has complied satisfactorily with the contract requirements as to specified areas, the purchaser shall not be required to do additional work on such areas.

Acceptance of cut-over areas.

No cutting before payment.

SEC. 10. All and only designated live trees shall be cut. No timber shall be cut until paid for, nor removed from the place or places agreed upon for scaling until scaled, measured, or counted by a Forest officer.

Damage to young growth.

SEC. 11. No unnecessary damage shall be done to young growth or to trees left standing, and no trees shall be left lodged in the

process of felling. Undesignated trees which are badly damaged in logging shall be cut if required by the Forest officer in charge.

Penalty for carelessness and waste.

SEC. 12. Undesignated live trees which are cut, or injured through carelessness, and designated trees left uncut on areas on which logging has been completed shall be paid for at double the current price for the class of material which they contain fixed in accordance with the terms of this agreement. Timber wasted in tops or stumps, designated timber broken by careless felling, and any timber merchantable, acording to the terms of this agreement, which is cut and not removed from any portion of the cutting area when operations on such portion are completed, or before this agreement expires or is otherwise terminated, shall be paid for at the current price for such material. The amounts herein specified shall be regarded as liquidated damage and may be waived in the discretion of the Forest officer in charge in accidental or exceptional cases which involve small amounts of material. Any timber remaining on the sale area at the expiration or termination of this agreement, for which payment as specified in this section has been made to the United States, may be removed within six months from such date of expiration.

Stump height and top diameter.

SEC. 13. All cutting shall be done with a saw when practicable; stumps shall be cut so as to cause the least practicable waste and not higher than eighteen (18) inches on the side adjacent to the highest ground for all trees with a diameter of twenty-four (24) inches and under at a point 4½ feet from the ground, and not higher than twenty-four (24) inches on the side adjacent to the highest ground for all trees with a diameter over twenty-four (24) inches at the point described, except in unusual cases when in the discretion of the Forest officer in charge this height is not considered practicable; all trees shall be utilized to as low a diameter in the tops as practicable and to a minimum diameter of ten (10) inches for Alaska cedar and six (6) inches for all other species when merchantable in the judgment of the Forest officer in charge. The log lengths shall be varied so as to secure the greatest possible utilization of merchantable material.

Wood used as fuel.

SEC. 14. Wood taken from tops or unmerchantable timber for use as fuel in connection with logging operations shall be allowed free of charge.

SCALING AND MERCHANTABILITY.

Measurement.

SEC. 15. Material shall be piled, rafted, or skidded for scaling, measurement, or count if required by the Forest officer in charge and in such manner as he shall direct. Logs will be measured in cubic feet on the basis of the length and the average middle diameter inside the bark taken to the nearest inch, or, if it is impracticable to secure the average middle diameter, on the basis of the length and the average of the diameters inside bark at the two ends of the log, each measured to the nearest inch.

SEC. 16. If any pulpwood is cut in the form of cordwood instead of in logs, it shall be measured in cords of 128 cubic feet of stacked wood, and the number of cords converted into cubic feet at the ratio of one cord equaling 100 cubic feet unless or

until, as the result of actual measurements, the district forester and the purchaser shall have agreed on the use of some other ratio. Such material shall be piled for measurment as the Forest officer in charge shall direct.

Scaling length.

SEC. 17. In obtaining the cubic contents of logs the maximum measuring length may in the discretion of the district forester be thirty-two feet; greater lengths may be measured as two or more logs.

Definition of merchantable tree.

SEC. 18. Any tree which in the judgment of the Forest officer contains one or more logs merchantable as defined in section 19, and having a net total merchantable volume of 25 per cent or more of the total volume of the tree, shall be considered merchantable under the terms of this agreement.

Merchantability defined.

SEC. 19. All spruce logs are merchantable under the terms of this agreement which are not less than 16 feet long, at least 6 inches in diameter inside bark at the small end, and after deductions for visible indications of defect are estimated to contain 33⅓ per cent sound material; all Alaska cedar logs are merchantable under the terms of this agreement which are not less than 16 feet long, at least 10 inches in diameter inside bark at the small end, and after deductions for visible indications of defect are estimated to contain 33⅓ per cent sound material; and all logs of hemlock and other species are merchantable under the terms of this agreement which are not less than 16 feet long, at least 6 inches in diameter inside bark at the small end, and after deductions for visible indications of defect are estimated to contain 50 per cent sound material: *Provided*, That the 33⅓ per cent aforesaid in spruce and Alaska cedar logs and the 50 per cent aforesaid in hemlock and other species shall be so located in the log as to permit the use of the sound material for pulp manufacture under the pulp manufacturing methods used in efficiently conducted pulp operations in Alaska.

Scale reports.

SEC. 20. On request, copies or abstracts of the scale reports will be furnished to the purchaser after they have been approved by the forest supervisor.

BRUSH DISPOSAL.

Disposal of brush.

SEC. 21. The district forester may require that all tops shall be lopped and all brush scattered so as to lie close to the ground and away from standing trees and reproduction, or any other method of disposal the cost of which shall not be in excess of this method.

FIRE PROTECTION.

SEC. 22. During the time that this agreement remains in force the purchaser shall independently do all in his power to prevent and suppress forest fires on the sale area and in its vicinity, and shall require his employees, contractors, and employees of contractors to do likewise. Unless prevented by circumstances over which he has no control, the purchaser shall place his employees, contractors, and employees of contractors at the disposal of any authorized Forest officer for the purpose of fighting forest fires, with the understanding that unless the fire-fighting services are

Assistance in fighting fires.

rendered on the area embraced in this agreement or on adjacent areas within one mile, payment for such services shall be made at rates to be determined by the Forest officer in charge, which rates shall be not less than the current rates of pay prevailing in the said National Forest for services of a similar character: *Provided,* That the maximum expenditure for fire fighting without remuneration in any one calendar year, at rates of pay determined as above, shall not exceed $10,000, including the furnishing of special trains or other special service as required; and further provided that if the purchaser, his employees, contractors, or employees of contractors are directly or indirectly responsible for the origin of the fire, no payment shall be made for services so rendered, nor shall the cost of such services be included in determining said maximum expenditure for any calendar year.

It is further agreed that except in serious emergencies as determined by the Forest supervisor the purchaser shall not be required to furnish more than 100 men for fighting fire outside of the area above specified, and that any employees furnished shall be relieved from fire fighting on such outside areas as soon as it is practicable for the Forest supervisor to obtain other labor adequate for the protection of the National Forest.

Spark arresters.

Fire equipment.

SEC. 23. If required by the Forest supervisor in writing, all donkey engines or other steam-power engines shall, during the period from June 1 to October 1 of each year, burn oil, or shall be equipped with spark arresters acceptable to the Forest officer in charge, six (6) 12-quart pails, six (6) shovels, and a constant supply of not less than the equivalent of twelve (12) barrels of water, this equipment to be suitable for fire-fighting purposes, and kept in serviceable condition.

Burning of refuse.

SEC. 24. During the period from June 1 to October 1 of each year, no refuse, brush, slash, or débris shall be burned without the written consent of the Forest officer in charge.

Transportation on logging roads.

SEC. 25. Officers of the Forest Service, fire fighters, and other regular and temporary employees shall be transported free of charge over logging roads operated in connection with this sale not common carriers, and shall be permitted to ride upon logging trains and engines or to operate speeders when traveling upon official business. Forest officers and other employees riding on logging trains, engines, or speeders shall do so at their own risk, and the owner of the railroad expressly reserves the right to enter into an agreement with such persons before entering upon said trains or engines, or before operating a speeder, releasing the said owner from liability for any injury sustained by them in riding on said trains, engines, or speeders, arising from any cause whatsoever. In emergencies arising from forest fires, special trains shall be furnished to officers and employees of the Forest Service.

OCCUPANCY.

Logging, improvements.

SEC. 26. The purchaser is authorized to build on National Forest land, sawmills, camps, railroads, roads, and other improvements necessary in the logging or the manufacturing of the timber included in this agreemnt: *Provided,* That all such structures

and improvements shall be located and operated subject to such regulation by the Forest officer in charge as may be necessary for the protection of National Forest interests. The continuance or operation of such improvements on National Forest land after this agreement has terminated shall be subject to authorization by permit or easement under United States laws, and unless such authorization is secured all improvements not removed shall become the property of the United States at the expiration of six months from the termination of this agreement.

Construction timber.

SEC. 27. All merchantable timber used in the construction of buildings, roads, and other structures, necessary in connection with the cutting and removal of the timber covered by this agreement, shall be paid for at the current rates for such material under this agreement. Cull material and unmerchantable tops of any species may be used for such purposes without charge and shall be left in place where used.

Sanitation of camps.

SEC. 28. Logging camps, mills, stables, and other structures, and the ground in their vicinity, shall be kept in a clean, sanitary condition, and rubbish shall be removed and burned or buried. When camps or other establishments are moved from one location to another or abandoned, all débris shall be burned or otherwise disposed of as the Forest officer in charge shall direct.

MISCELLANEOUS.

Representative of purchaser.

SEC. 29. At all times when logging operations are in progress the purchaser shall have at the main camp for his employees working on the sale area a representative who shall be authorized to receive, on behalf of the purchaser, any or all notices and instructions in regard to work under this agreement given by the Forest officer in charge, and to take such action thereon as is required by the terms of this agreement.

Complaints by purchaser.

SEC. 30. Complaints by the purchaser arising from any action taken by a Forest officer under the terms of this agreement shall not be considered unless made in writing to the Forest supervisor having jurisdiction within thirty (30) days of the alleged unsatisfactory action. The decision of the Secretary of Agriculture shall be final in the interpretation of the regulations and provisions governing the sale, cutting, and removal of the timber covered by this agreement.

Suspension of operations.

SEC. 31. All operations on the sale area, including the removal of scaled timber, may be suspended by the district forester, in writing, if the conditions and requirements contained in this agreement are disregarded, and failure to comply with any one of said conditions and requirements, if persisted in, shall be sufficient cause for the termination of this agreement: *Provided*, That the district forester may, upon reconsideration of the conditions existing at the date of sale and in accordance with which the terms of this agreement were fixed, and with the consent of the purchaser, terminate this agreement, but in the event of such termination the purchaser shall be liable for any damages sustained by the United States arising from the purchaser's operations hereunder.

Inspection of books.

SEC. 32. All the books pertaining to the purchaser's logging operation and milling business shall be open to inspection at any time by a Forest officer authorized by the district forester to make such inspection, with the understanding that the information obtained shall be regarded as confidential.

Definition of "Forest officer."

SEC. 33. The term "officer in charge" wherever used in this agreement signifies the officer of the Forest Service who shall be designated by the proper supervisor or by the district forester to supervise the timber operations in this sale.

Act of March 4, 1909.

SEC. 34. No Member or Delegate to Congress, or Resident Commissioner, after his election or appointment, and either before or after he has qualified, and during his continuance in office, shall be admitted to any share or part of this contract or agreement, or to any benefit to arise thereupon. Nothing, however, herein contained shall be construed to extend to any incorporated company, where such contract or agreement is made for the general benefit of such incorporation or company. (Section 3741, Revised Statutes, and sections 114–116, Act of March 4, 1909.)

Contract nonassignable.

SEC. 35. This agreement shall not be assigned in whole or in part.

Authority to modify agreement.

SEC. 36. The conditions of the sale are completely set forth in this agreement, and none of its terms can be varied or modified except in writing by the Forest officer approving the agreement, or his successor or superior officer, and in accordance with the regulations of the Secretary of Agriculture. No other Forest officer has been or will be given authority for this purpose.

SEC. 37. And as a further guarantee of a faithful performance of the conditions of this agreement we deliver herewith a bond in the sum of Fifty Thousand Dollars ($50,000.00), and do further agree that all moneys paid under this agreement shall, upon failure on our part to fulfill all and singular the conditions and requirements herein set forth, or made a part hereof, be retained by the United States to be applied as far as may be to the satisfaction of our obligations assumed hereunder. We do further agree that should the sureties on the bond delivered herewith or on any bond delivered hereafter in connection with this sale become unsatisfactory to the officer approving this agreement, we will within thirty (30) days of receipt of demand furnish a new bond with sureties solvent and satisfactory to the approving officer.

Signed in duplicate this _____ day of _____, 192__.

[CORPORATE SEAL.]

By _____

_____

Its _____

Witnesses:

_____

_____

Approved at Washington, D. C., under the above conditions, _____

_____, 192__.

_____,

Forester.

Index to units, names of power sites, and approximate capacities.

	Unit.	Name.	Possible horse-power.
A	Thorne Arm	Fish Creek	10,000
B	Carrol Inlet	Swan Lake	9,000
C	Ketchikan Region	Beaver Falls	5,000
C	do	Naha Creek	5,000
D	Shrimp Bay	Shrimp Bay	7,000
D	do	Bailey Bay	6,000
E	Mill Creek	Mill Creek	4,000
F	Karta Bay	Karta River	4,000
G	Sulzer	Coppermount	4,000
H	Thomas Bay	Thomas Bay	15,000
I	Sweetheart Falls	Sweetheart Falls	15,000
J	Speel River	Speel River	20,000
J	do	Long Lake	10,000
J	do	Crater Lake	
J	do	Tease Lake	5,000
K	Juneau	Treadwell	[1] 10,000
K	do	Alaska-Gastineau	[1] 12,000
K	do	Cowie Creek	2,000
L	Mitchell Bay	Mitchell Bay	10,000
M	Warm Springs Bay	Warm Springs Bay	5,000
M	do	Cascade Bay	5,000
N	Silver Bay	Silver Bay	6,000
O	Neutral	Basket Bay	2,000
O	do	Gut Bay	2,000
O	do	Patterson Bay	5,000

[1] Developed.

PORTION OF
TONGASS NATIONAL FOREST
ALASKA
SCALE ON 56TH PARALLEL
(ABOUT 25 MILES = 1 INCH)
NATIONAL FOREST BOUNDARY
AREA SOLD
AREA CRUISED
AREA BEING CRUISED
UNIT BOUNDARY
AREAS OF BEST TIMBER
HYDRO-ELECTRIC POWER SITE AND M.H.P. ⊙(6)=6000 H.P.
UNITS
A Thorn Arm
B Carroll Inlet
C Ketchikan Region
D Shrimp Bay
E Mill Creek
F Karta Bay
G Sulzer
H Thomas Bay
I Sweetheart Falls
J Speel River
K Juneau
L Mitchell Bay
M Warm Spring Bay
N Silver Bay
O Neutral Territory
PACIFIC OCEAN
MILITARY CABLE TO SEATTLE
BRITISH COLUMBIA
UNITED STATES
DYEA
Skagway
Klukwan
Jualin
CROSS SOUND
CHICHAGOF ISLAND
LYNN CANAL
JUNEAU
Gypsum
Tenakee
Taku
GLASS PENINSULA
Sheltisham
SITKA
BARANOF ISLAND
CHATHAM STRAIT
FREDERICK SOUND
Kake
KUPREANOF ISLAND
Petersburg
Woedski
SUMNER STRAIT
WRANGELL
STIKINE RIVER
IPHIGENIA BAY
LARENCE STRAIT
Ernest Sound
Hollis
Sulzer
Kiam
BEHM CANAL
Waring
KETCHIKAN
Howkan
Klinkwan
Niblack
PRINCE OF WALES ISLAND
REVILLAGIGEDO ISLAND
Revillagigedo Channel
Port Simpson
PRINCE RUPERT
Port Essington
GRAND TRUNK PACIFIC R.R.
SKEENA R.
Approximate Data

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 931

Contribution from the Bureau of Public Roads, THOS. H. MacDONALD, Chief
in cooperation with the Office of Farm Management and
Farm Economics, H. C. TAYLOR, Chief

Washington, D. C. ▼ February 25, 1921

CORN-BELT FARMERS' EXPERIENCE WITH MOTOR TRUCKS

A STUDY OF 831 REPORTS FROM FARMERS WHO OWN MOTOR TRUCKS

By

H. R. TOLLEY, Agricultural Engineer, and
L. M. CHURCH, Assistant in Farm Accounting

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1921

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 932

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER September 20, 1921

LIFE HISTORY OF THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO

By

E. H. SIEGLER, Entomologist, and H. K. PLANK, Scientific Assistant, Fruit Insect Investigations, in Cooperation with The Colorado Agricultural Experiment Station

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 933

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. PROFESSIONAL PAPER March 8, 1921

BLACK WALNUT

ITS GROWTH AND MANAGEMENT

By

F. S. BAKER, Forest Examiner

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1921

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 934

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 16, 1921

DAMPING-OFF IN FOREST NURSERIES

By

CARL HARTLEY, formerly Pathologist, Office of Investigations in Forest Pathology

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GOVERNMENT PRINTING OFFICE
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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 935
Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C. ▼ March 14, 1921

THE DISTRIBUTION OF NORTHWESTERN BOXED APPLES

By

C. W. KITCHEN, Specialist in Market News, Fruits, and Vegetables; E. M. SEIFERT, Jr., Assistant in Market Surveys; and MARY B. HALL, Clerk

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 943

Contribution from the Office of Farm Management and Farm Economics
H. C. TAYLOR, Chief

Washington, D. C. ▼ April 30, 1921

COST OF PRODUCING WHEAT

ON 481 FARMS IN THE STATES OF NORTH AND SOUTH DAKOTA, MINNESOTA, KANSAS, NEBRASKA, AND MISSOURI, FOR THE CROP YEAR 1919

By

M. R. COOPER and R. S. WASHBURN
Assistant-Farm Economists

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 945

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER May 27, 1921

THE INFLUENCE OF CALCIUM AND PHOSPHORUS IN THE FEED ON THE MILK YIELD OF DAIRY COWS

By

EDWARD B. MEIGS, Physiologist, and T. E. WOODWARD,
Dairy Husbandman, of the Dairy Division

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 947

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER. October 11, 1921

WESTERN SNEEZEWEED (HELENIUM HOOPESII) AS A POISONOUS PLANT

By

C. DWIGHT MARSH, Physiologist in Charge of Investigations of Stock Poisoning by Plants; A. B. CLAWSON, Physiologist; JAMES F. COUCH, Pharmacological Chemist, and HADLEIGH MARSH, Veterinary Inspector, Bureau of Animal Industry

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 948

Joint Contribution from the Bureau of Markets, GEORGE LIVINGSTON, Chief, and the Bureau of Chemistry, CARL L. ALSBERG, Chief

Washington, D. C. September 10, 1921

COMPOSITION OF COTTON SEED

By

CHARLES F. CRESWELL, formerly Specialist in Marketing Vegetable Oils, Bureau of Markets,

and

GEORGE L. BIDWELL, Chemist in Charge, Cattle Food Laboratory, Miscellaneous Division, Bureau of Chemistry

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 949

Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C. October 10, 1921

STANDARD AND TENTATIVE METHODS OF SAMPLING AND TESTING HIGHWAY MATERIALS

Recommended by the

SECOND CONFERENCE OF STATE HIGHWAY TESTING ENGINEERS AND CHEMISTS

Washington, D. C., February 23 to 27, 1920

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 950

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. PROFESSIONAL PAPER June 15, 1921

REGIONAL DEVELOPMENT OF PULPWOOD RESOURCES OF THE TONGASS NATIONAL FOREST ALASKA

By

CLINTON G. SMITH, Forest Inspector

Alaska—Tongass and Chugach National Forests.

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